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Operating Safety and Requirements of the Modern Transport

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ABSTRACT AND SUMMARY OF CONCLUSIONS

Four principal emergencies occurring during operation of transport airplanes are investigated: (1) power plant failure during take-off, (2) power plant failure during normal flight, (3) misjudged landing with climb-out from the field, and (4) adverse operating conditions at low efficiency, such as with an irregular load of ice. Landing speed and control at low speed are also studied.

The use of coordinated design to provide added operating safety and efficiency of transport aircraft is demonstrated. By viewing problems actually confronting the transport pilot and considering emergencies that arise, figures of merit are obtained for safety of operation during take-off, landing approach, landing into the field, and flight under icing conditions.

Revenue is more directly affected by operating safety than by other factors such as speed, economy, and comfort. Furthermore, revenue is the most important factor in efficient and economical operation of an airline.

The modern transport airplane can be designed and tested for attractive operating safety. Requirements, unless especially adopted to encourage design for maximum safety, might lead to use of devices and techniques which actually decrease safety. Use of special landing or take-off devices must be carefully coordinated with the existing condition or emergency.

Operating safety throughout the year requires ability to fly at emergency performance under any existing adverse conditions. Such assurance in flight is of paramount importance to transport flying.

Four engines are desirable for safe all-year operation of long- and medium-range airplanes because of the large reserve of power after propulsive unit failure. The two-engine airplane seems suitable for short-range operation where, with small fuel load, a good payload can be maintained without exceeding safe loading.

The tricycle landing gear has exceptional stability on the ground, hence contributes both to fool-proof take-off and landing, particularly under adverse conditions. Greater load can be landed in shorter distance with the tricycle gear, hence it adds safety and efficiency to an airplane. With the normal landing gear equivalent safety and stability can hardly be obtained at any loading.

DURING the design of a major airliner the designer's thoughts cover many problems. He considers safety, economy, speed, and comfort, *i.e.*, the needs of the air traveler. It is especially important that the designer coordinate all to an efficient degree by broad unified study. For this reason, studies of economy, speed, and operating safety have been actively made over the past three years on the DC-4 by the aerodynamics group.

SAFETY AND EFFICIENCY

The entire foundation of operating economics depends upon revenue. Every study of operations shows that the factor most directly affecting the success of an airline is the volume of cargo and traffic passing over the system. Whereas all individual items of expense affect the gross operating cost to a greater or lesser degree, the volume (or revenue) is the very life of the system and thus most directly affects the final result.

Revenue is most changeable and experience shows that it fluctuates most with the apparent safety of flying. There is relatively small variation with economy, reliability, speed, and comfort. The achievement of a higher degree of safety, even at the expense of higher initial cost and longer, more difficult development

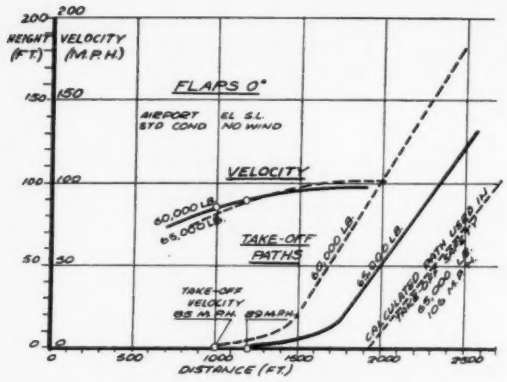

FIG. 1. Flight test take-off path of the DC-4. Take-off paths are based on the average of flight test results at 60,000 pounds.

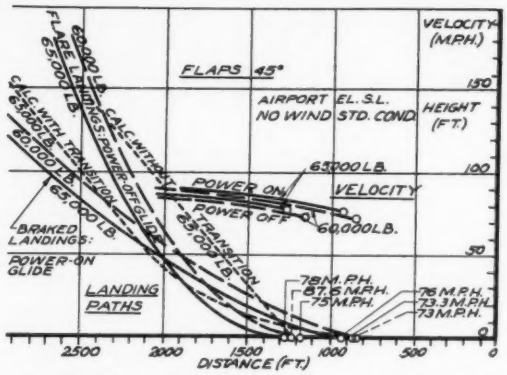

FIG. 2. Flight test landing path of the DC-4 with flaps 45°. Landing paths are based on the average of flight test results at 60,000 pounds.

period, will ultimately have a beneficial effect upon successful and profitable operation.

SAFETY REQUIREMENTS

Operations which give an indication of safety of transportation in airline flying should be carefully investigated. While normal take-off distance, landing speed, angle of climb, take-off and landing over obstacles furnish an indication of the actual performance of the airplane under ideal conditions, their shortcomings are directly realized when attempting to analyze the safety of operations.

Consider the curves of flight test results on take-off and landing paths of the DC-4 shown in Figs. 1 and 2. Do these test results show that the airplane can be operated on a field having obstacles with 5 percent, 15 percent, or 100 percent of the distances shown? What margin of height is sufficient? Will the airplane be considered safe for operation over an obstacle which it just clears in the curving transition stage during take-off, or in the transition during landing? Is the landing speed an adequate measure? Such questions must be answered before a consistent degree of operating safety can be achieved.

The actual operation of the airplane on the airline, the most imminent emergency case, its most apparent danger, these must be studied to achieve advancement and great safety. Such investigation will disclose certain requirements that are difficult to achieve, but a thorough investigation is the best manner of obtaining real safety. For this purpose a close approximation of the actual case at hand is far better than a detailed investigation of some operation which does not represent the entire problem.

Experience shows that if safety is to be achieved, the most probable emergency conditions must be provided for. These conditions depend somewhat upon the airplane and upon the season of the year. Safety will in addition, depend upon the structural service and integrity of the aircraft; likewise, it depends upon the power plant. It is evident from experience that the following emergencies will at some time arise, even though improvement in all items causing these emergencies is steadily being pursued. (1) Power plant failure during take-off; (2) power plant failure during normal flight; (3) a misjudged landing in which the airplane will again have to circle the field; (4) icing condition wherein the airplane efficiency is reduced by an irregular load of ice.

Besides these emergency requirements, certain normal operating characteristics must be satisfactory. These are principally: the complete take-off, the complete landing, and the control and speed during the glide approach to the airport.

POWER PLANT FAILURE

The probability of failure of a certain number of power plant units is a function of the total number of engines. The mathematical relation for the probability of failure derived from a study of probabilities of various combinations can be expressed as:

$$p_{nk} = \frac{n(n-1).\ldots.(n-k+1)}{k!}\, r^k \qquad (1)$$

where n = total number of engines; k = number of failures; r = probability of failure of one unit. r is expressed in terms of failures per hour, or per operation, such as take-off, trip, etc. This equation enables one to make a quantitative study of the desirability of various multi-engine installations for any particular reliability and safety requirement.

Assuming one failure every 1000 operations ($r = {}^1/_{1000}$) the number of failures to be expected in 1,000,000 operations for various types of multi-engine installations are given in Table 1.

The data in this table verify the general conclusion that greatest safety is obtained from the configuration that can fly after failure of the largest number of engines. Variation of single failure probability after power plant failure is neglected in this simplified tabulation.

TABLE 1

Number of Engines (n)	1,000,000 p_{nk} = Failures per 1,000,000 Operations, of				
	1 Engine ($k = 1$)	2 Engines ($k = 2$)	3 Engines ($k = 3$)	4 Engines ($k = 4$)	5 Engines ($k = 5$)
1	1,000				
2	2,000	1			
3	3,000	3	.001		
4	4,000	6	.004	.000001	
5	5,000	10	.010	.000005	.000000001
6	6,000	15	.020	.000015	.000000006
7	7,000	21	.035	.000035	.000000021
8	8,000	28	.056	.000070	.000000056
9	9,000	36	.084	.000126	.000000126
10	10,000	45	.120	.000210	.000000252

The comparable order of safety is given by the number of failures, rather than the total number of engines. For example, whereas on two- and four-engine airplanes there would be two thousand and four thousand single failures, respectively, every 1,000,000 operations, the number of two-engine failures is one and six, respectively, every 1,000,000 operations. The logical emergency condition from the standpoint of failure is, therefore, that of one unit out of operation for all practical designs. The possibility of flight after failure of two engines gives an operation with a distinctly higher order of reliability which, at the present time, is secondary to the performance resulting when the much more probable single failure occurs.

Airline experience has shown that single failure during take-off and in the air has occurred frequently enough to be of much concern. Therefore, operating safety cannot be claimed without consideration of a failure during any part of the operation. This consideration is strengthened by the fact that a single-engine airplane is not permitted as an airline carrier except for contact flying which, of course, states that a power plant failure is a distinct hazard at all times.

TAKE-OFF SAFETY

During the take-off operation, there is generally one region in which the failure of an engine would produce a critical condition. It has been shown that measurement of the normal take-off operation as shown in Fig. 1, gives no clue to the operating safety, because the diagram is the same for a single-engine airplane as for a multi-engine airplane. Furthermore, it must be realized that an engine failure might occur at any position during operation. Therefore the criterion for take-off safety has been chosen as follows:

If during the take-off an engine failure occurs, the pilot has the alternative of continuing his flight or landing within the boundaries of the field. If the failure occurs at an early stage of the take-off, he will remain on the ground. If the failure occurs after he has gained considerable altitude, he will continue his flight. However, if the failure occurs in the intermediate region, a critical condition is likely to result. For this purpose, the take-off path with failure at any point during the take-off condition is calculated, assuming both that the pilot continues flight and that he lands. This procedure is illustrated in Fig. 3.

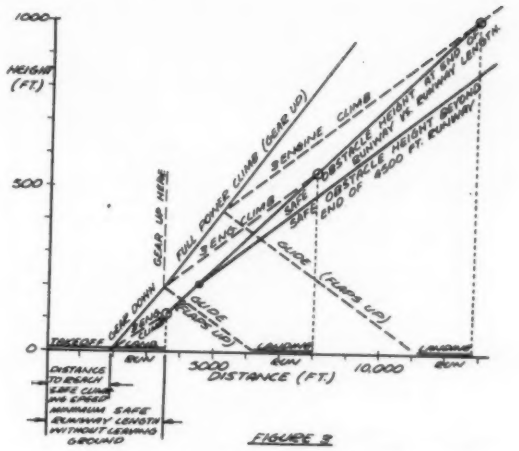

FIG. 3. Illustration of take-off safety calculation.

Complications which obviously would only lead to useless detail have been avoided in order to render a practical solution of the entire problem. For example, a two-phased take-off is used in which it is assumed that the airplane gains climbing speed on or near the ground in the first phase, and proceeds at the climbing angle in the second phase. Results show that the take-off flare is unnecessary for this analysis. Obstacles which could barely be cleared during the take-off flare would certainly be ruled out in any practical operation.

The climbing speed has been assumed half-way between the stalling speed and the maximum L/D speed as an approximation to the best climbing angle. This speed, of course, should remain approximately 20 percent above the stall. The airplane continues along the path given by the angle of climb after engine failure, with propeller feathered if so equipped, or glides to a landing and stops. The flaps during this landing are kept in the take-off position as would probably be the case in actual operation. The landing is assumed to be made at the speed of the glide because the pilot, in all probability, would attempt to place the airplane on the ground as soon as possible. With the normal landing gear, the attitude during the landing roll is maintained constant; that is, the airplane is held at the given angle of attack of landing. With the tricycle gear, the airplane instantly rocks forward onto the nose wheel.

The height of the airplane on the continued flight path above the end of the landing roll in case the airplane lands and stops is the height of the obstacle at the end of the field over which, or within which, the airplane can safely operate during this emergency condition.

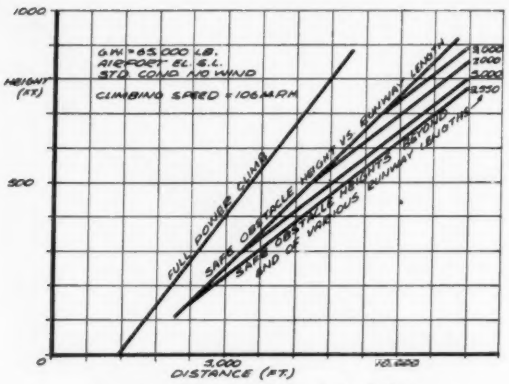

FIG. 4. Take-off safety of the DC-4.

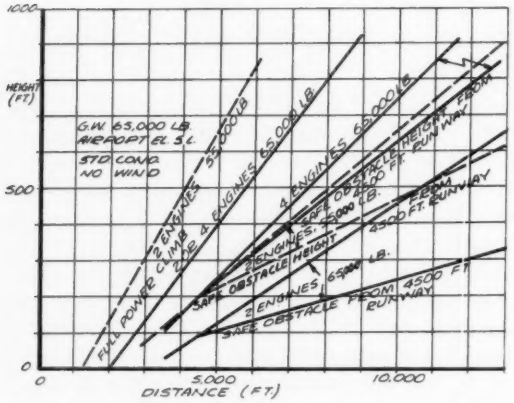

FIG. 5. Take-off safety of the DC-4, showing comparison with a similar two-engine airplane.

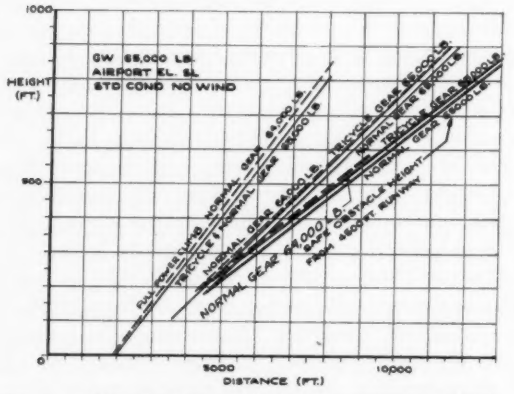

FIG. 6. Take-off safety of the DC-4, comparing tricycle and normal landing gear.

The locus of such points, shown on Fig. 3, produces a line from which can be drawn the path angle after engine failure to determine the take-off safety path of the airplane for operation from fields of various lengths. Results of this type are illustrated in Fig. 4. Two directions of lines are adequate for defining take-off safety of an airplane.

Several interesting facts are brought out by this representation of take-off operating safety.

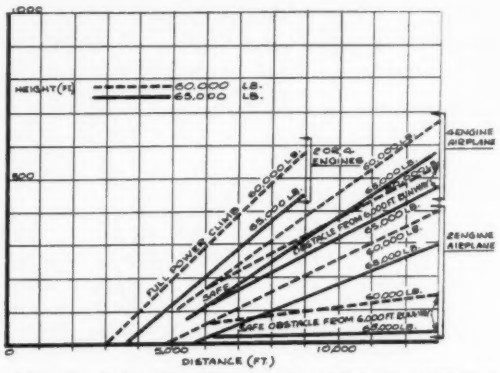

FIG. 7. Take-off safety of the DC-4 at 5,000 feet altitude, showing the effect of weight and number of engines. Temperature 110°F.; no wind.

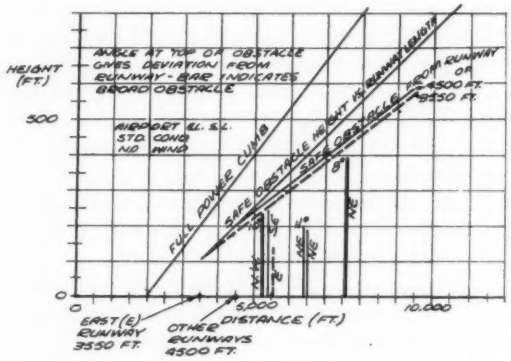

FIG. 8. Take-off safety for the DC-4 with gross weight = 65,000 lb.

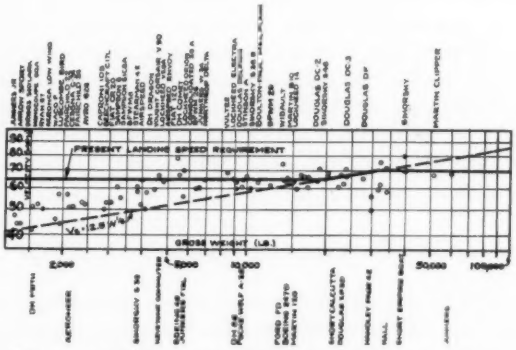

FIG. 9. Landing speed versus gross weight for contemporary airplanes.

(1) The reserve power after engine failure has an effect upon take-off safety. This fact is illustrated by Fig. 5, which compares take-off safety for the four-engine DC-4 versus that of a similar two-engine airplane. It is interesting to note here the reduction in gross weight of a two-engine airplane that must be made in order to provide a similar margin of safety in the take-off. The two-engine airplane will be most suitable where fuel load is low; such as, for short range feeder line operation where the payload can remain an appreciable amount.

(2) The type of landing gear and the landing characteristics have a marked effect upon the operating safety. This result is illustrated by Fig. 6 in which the take-off safety curves are given for the DC-4 equipped both with normal and tricycle gear. Here again is shown the considerable reduction in weight that is necessary if equivalent safety is to be obtained with the normal gear. No advantage has been assumed in this calculation for the improved ground stability of the tricycle gear.

It is especially significant that additional complication and weight of the four-engine design and the tricycle gear is justified by the results achieved. Greater payload can be carried with greater safety by the use of these provisions.

In order to illustrate the application of this operation, the take-off safety paths are presented in Fig. 7 for the DC-4 at altitude with high temperature and for two gross weights. By the use of diagrams of this type in conjunction with airport dimensions and obstacles, it is possible to insure equivalent operating safety throughout an airline for various airport dimensions and atmospheric conditions, as illustrated in Fig. 8. By adding temperature and wind effects, the safe weight for prevailing conditions can be calculated.

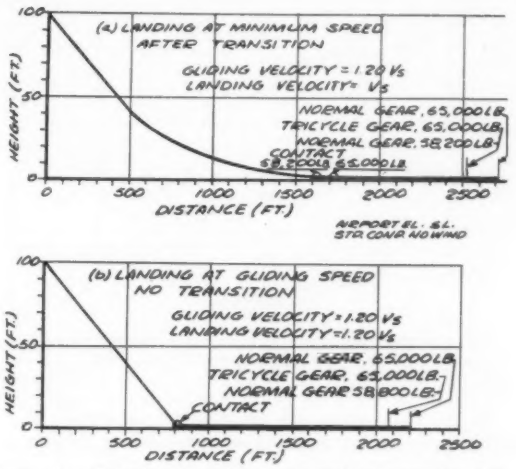

FIG. 10. Calculated landing path and distance for the DC-4 with flaps at 45°.

LANDING SAFETY

It is generally agreed that landing speed is not the proper figure of merit for safety. Yet, it is the only specific requirement in existence today for our transports. Physical reasoning and statistics of landing speed trend with weight as given in Fig. 9 show that the larger airplane can logically land at higher speed than the smaller airplane. In case of collision, the greater local stiffness, larger dimensions, and higher inertia of the large airplane makes it comparatively safer. It has more shielded protection and greater mass for coping with obstacles. The increase in landing speed with gross weight is logical and practically inevitable. The actual trend corresponding to geometric similarity is shown in Fig. 9, following approximately the sixth root of the weight ($W^{1/6}$). This is equivalent to constant density; *i.e.*, weight variation with the cube of a characteristic dimension (such as, weight varies as area$^{3/2}$).

Still, landing speed gives no indication of the more important criteria of landing gear characteristics and control near the stall, or of safe landing operations. Comparative landing run with normal gear and tricycle gear is shown in Fig. 10. Flight experience with the tricycle gear shows it to be adaptable to large airplanes with excellent results.

With the landing path as with the take-off path, Fig. 2 fails to give a complete measure of landing safety. For continued safety, operation near this limit is not advisable. It is necessary to find some criterion for safety and the margin needed for emergency must be evaluated.

There are two periods in the landing operation that are of major importance to the pilot: (1) the landing approach during which the airplane is brought down to the edge of the field, and (2) the final glide-in and landing operation.

LANDING APPROACH

The landing approach must be at sufficiently low speed to allow time for the pilot to locate himself and properly orient the airplane for the blind approach with existing radio marker beam layout. The present requirement, which cannot be changed unless radio approaches are revised, is that the airplane speed should not exceed approximately 120 m.p.h., because of reaction time needed. Still the airplane must have sufficient margin to be controllable at that speed in approximately a 45° bank. Lateral control must have a given minimum effectiveness, longitudinal stability must be good, directional control ample. Stalling characteristics are of great importance. An airplane with warning of and slow entry into a stall can be flown at an approach speed considerably below that of another having a lower stalling speed, but exhibiting marginal or reversal of control, and sharp drop-off.

If the pilot should suddenly discover that he were drifting off course and approaching an obstacle, a reserve of power or climbing angle would be necessary to enable him to avoid the obstacle and safely make another approach.

For the reason that climbing angle is adversely affected by large flap angles and landing gear when in the down position, the approach is generally made flaps up in order to maintain high performance. The variation of climbing angle of the DC-4 at take-off power with flap setting when the landing gear is up, is shown in Fig. 11.

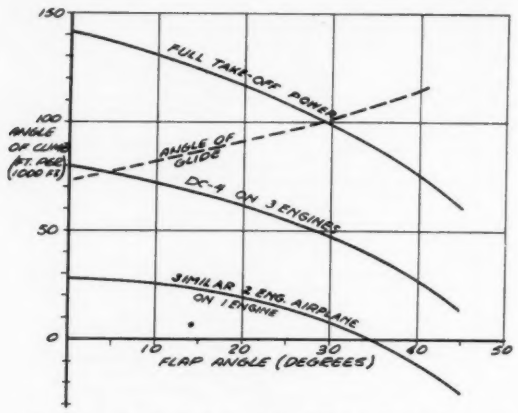

FIG. 11. Angle of climb of the DC-4 and a similar two-engine airplane versus flap angle. Gross weight = 65,000 lb.; standard conditions.

If, when using the flaps, the speed of approach is sufficiently above the stalling speed with flaps up, the flaps could be raised to reduce drag and assist in the climb-out. However, such procedure might not be possible when near the landing speed. Furthermore, in an emergency the pilot will be occupied in maneuvering, feathering propellers, raising landing gear, etc.

In all considerations of landing, the performance of the airplane with power applied is of greatest importance, since in emergencies, the landing operation can only be prevented by such application. Likewise in all considerations of landing, the case of landing with one engine out of operation is especially important because a landing must eventually always be made after any failure in the air. Significantly, the greater margin of power that remains after failure, the less the probability of having to land in a hazardous place.

Therefore, this angle of climb in the approach pull-out is presented in Fig. 11 for the DC-4 after engine failure, with comparison for a two-engine airplane. The minimum requirement will have to be established by experience. Although it is probable that the four-engine airplane might provide more reserve on three engines than necessary, it is evident that the two-engine airplane cannot be heavily loaded if it is to have ample climb.

LANDING OPERATION INTO FIELD

After the successful approach, the airplane still must land safely within the confines of the field, and within obstacles at either end. Therefore, the glide-in and landing must finally be considered in order to complete the landing safety investigation. As was pointed out earlier, the landing path alone, shown in Fig. 2, is not adequate for determining limits of landing operations, because of the fact that no provision is allowed for an emergency.

In cases of poor visibility and when the landing is made from under low overcast, or when the pilot's attention tends to be diverted because of generally adverse or emergency conditions, the probability exists of the necessity for climbing out and again circling the field for another attempt at landing. This possibility is existent up to the time when the airplane actually makes contact with the ground. Beyond this point it is reasonable to assume that the pilot has chosen his course and will remain on the ground. Thus, it appears that for a criterion of safety in landing operations, the airplane should be considered to glide in to the point of contact, at which point either the landing proceeds into the landing run or the alternative of a climb-out with power is made. The possibility of such operation provides a definite measure of safety and relieves the pilot of early apprehension regarding the outcome of his landing. Study of the landing angle and climb-out has disclosed various interesting facts, some of which are actually carried out in the operation of the airplane by the pilot, yet so far have received little attention by the engineer.

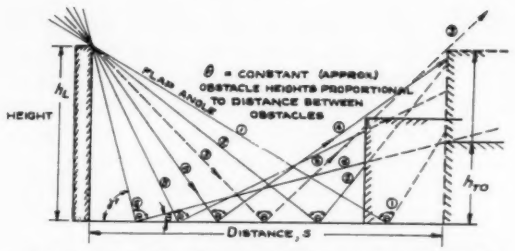

FIG. 12. Landing glide and climb-out paths, illustrating the variation of optimum flap angle with ratio of take-off and landing obstacle heights.

It is apparent that the angle between the gliding path and the climbing path with take-off power is approximately constant for all flap settings, due to the fact that the amount of power applied is constant. When flaps are down, the gliding angle will be steep and the climbing angle flat. When flaps are up, the gliding angle will be flat and the climbing angle steep. In some intermediate position, these two angles will become equal, as illustrated in Fig. 12. The amount of flap to be used in the landing operation is a function of the obstacle heights at the ends of the field. Large flap angles should be used when the high obstacle is over the approach, while small flap angles should be used when there is a low obstacle height the approach and a high obstacle height at the far e che field.

A relation obtained by considering variation in climbing and gliding angles with flap setting enables the determination of the optimum gliding angle as a function of the ratio of obstacle heights at the ends of the field. Referring to Fig. 12,

$$\Delta\beta = -K\Delta\gamma = -K(\gamma - \gamma_0) \qquad (2)$$

and the total distance to clear both obstacles is,

$$s = \frac{h_L}{\gamma} + \frac{h_{TO}}{\beta} = \frac{h_L}{\gamma} + \frac{h_{TO}}{\beta_0 - K(\gamma - \gamma_0)} \qquad (3)$$

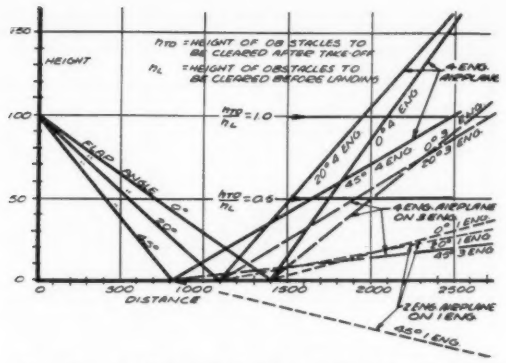

FIG. 13. Landing and climb-out path of the DC-4 and a similar two-engine airplane after engine failure. Gross weight = 65,000 lb.; airport elevation, sea level; standard conditions; no wind.

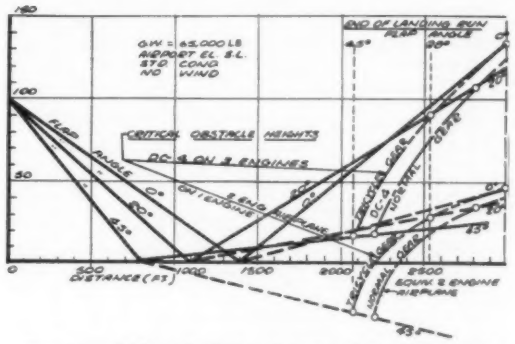

FIG. 14. Glide and climb-out paths of the DC-4 and a similar two-engine airplane after power plant failure. Shows effect of landing run and flap angle. The ordinate represents height in feet.

The optimum gliding angle $\gamma_{opt.}$ is found by setting the derivative equal to zero,

$$\frac{ds}{d\gamma} = -\frac{h_L}{\gamma^2_{opt.}} + \frac{Kh_{TO}}{[\beta_0 - K(\gamma_{opt.} - \gamma)]^2} = 0 \quad (4)$$

giving

$$\gamma_{opt.} = \frac{\beta_0 + K\gamma_0}{(Kh_{TO}/h_L)^{1/2} + K} \quad (5)$$

The optimum climbing angle $\beta_{opt.}$ is obtained from the relation,

$$\beta + \gamma = C - (K - 1)(\gamma - \gamma_0) \quad (6)$$

where:

β = Angle of climb.
γ = Angle of glide.
$\gamma_{opt.}$ = Best angle of glide, using flaps, if necessary.
$\beta_{opt.}$ = Corresponding best angle of climb.
β_0 = Angle of climb, flaps up.
γ_0 = Angle of glide, flaps up.
$K \approx 1.5$ (Slipstream effect on flap drag).
$K = 1.0$ (No slipstream effect).
C = Constant—angle due to thrust power.
h_L = Height of obstacle to be cleared before landing.
h_{TO} = Height of obstacle to be cleared after take-off.

While the landing gear is down during the glide, it is assumed retracted during the climb-out, since the pilot's action in raising the landing gear will be practically simultaneous with his decision to continue flight. Use of these equations determines the curves showing the degrees of flap recommended for landing of the DC-4, as shown in Fig. 13. It will be noted that without considering the effect of the landing run, the flap angle depends only upon ratio of obstacle heights and is independent of field length. The actual heights of the obstacles that can be cleared are proportional to the field length.

Comparison of landing and climb-out paths of the DC-4 after engine failure and that of a similar two-engine airplane is made in Fig. 13. In order to provide safety in the event of again circling the field, it is seen that the similar two-engine airplane has to be landed at a considerably lower gross weight.

For low obstacles, the landing run determines the field length, because of the fact that from the consideration of gliding angle and climb-out angle alone, the landing field length would approach zero for zero obstacle heights. The modified curves of the landing, andclimb-out path of the DC-4 after power plant failure, including the effect of the landing run, are shown in Fig. 14, which also shows comparison of the landing operation with normal gear. The shorter landing run with the tricycle gear permits safe operation from considerably shorter fields.

The complete landing operation is shown in Fig. 15. Comparison with take-off safety operation is given in Fig. 16. When studied to provide safety in emergency conditions, the following conclusions can be drawn:

(1) The reserve power after engine failure has an effect upon the landing safety, as illustrated in Fig. 16.

(2) The type of landing gear and landing characteristics have a marked effect upon the landing safety, particularly in short fields, as shown in Fig. 16.

(3) There is an optimum flap angle setting for greater safety in landing operation which generally is not the angle at which the lowest landing speed is obtained, as reference to Fig. 16 shows.

In many cases, and particularly in the case of landing after engine failure, use of full-flap reduces the performance to such an extent that it would be hazardous to make a landing in that condition. Therefore, the requirement for landing speed without consideration of factors adding to general safety of operation might lead to the adoption and use of devices which reduce landing safety.

CONTROL AT LOW SPEED

Up to this point, the main emphasis has been placed upon obtaining safety through performance. How-

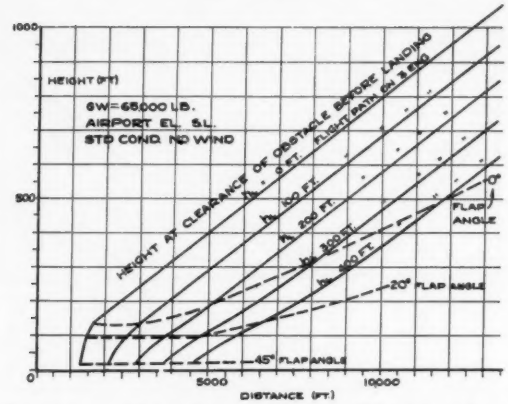

FIG. 15. Landing safety paths of the DC-4 for various obstacle heights to be cleared before landing.

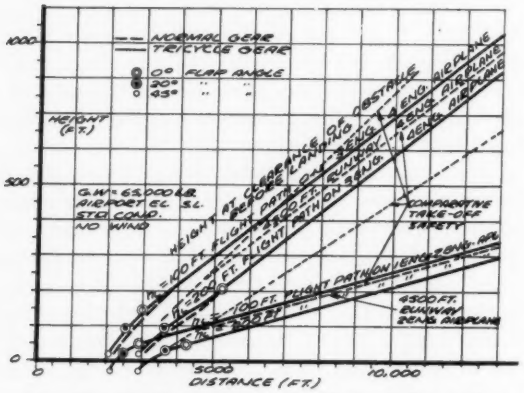

FIG. 16. Landing safety paths of the DC-4 and a similar two-engine airplane after engine failure showing effect of landing gear. A comparison with take-off safety is given.

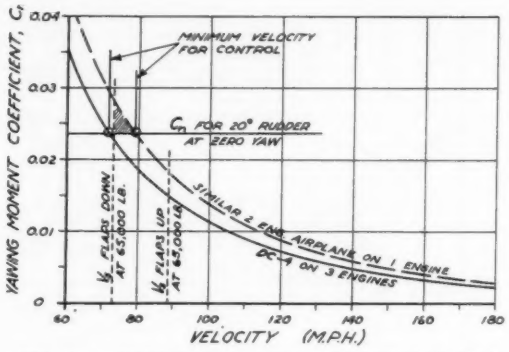

FIG. 17. Thrust moment and rudder control of DC-4 after engine failure versus velocity, compared with a two-engine airplane. Propeller on dead engine feathered, remaining engines operating at take-off power at sea level.

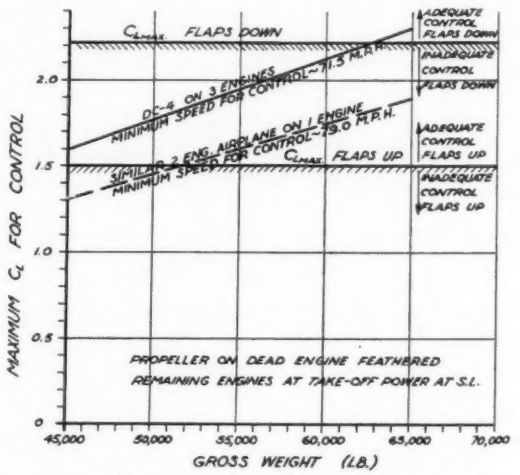

FIG. 18. Rudder control of the DC-4 after engine failure versus gross weight, compared with a two-engine airplane.

ever, there must be adequate control if advantage can be taken of the available performance, and if safety in emergency conditions is to be actually obtainable.

After an engine failure, equilibrium about the vertical axis is obtained by use of the rudder, which balances the offset thrust of the engines. Without ample yawing moment at low speed the airplane will be turned by the power moment, and if flight is then to be maintained, the power would have to be reduced, thereby causing a loss in rate of climb. The offset thrust changes little with velocity near the landing and take-off speeds. However, the available moment from a given vertical surface and rudder throw is proportional to the square of the velocity, hence it decreases rapidly as the velocity is reduced. Therefore, for an airplane with a high ratio of power to weight, it would be difficult to retain control at low speed. Take-offs and landings might become hazardous if carried out at or below the lowest speed at which balance is obtained with the vertical surface.

The vertical surface area of a multi-engine transport plane is designed to cope with this situation, not alone to provide directional stability. A vertical surface which gives the desired control after engine failure is more than ample for good directional stability. The variation of required moment coefficient after engine failure and the available coefficient is shown for the DC-4 in Fig. 17. Comparison is also shown with a similar two-engine airplane wherein it is apparent that equivalent control can only be obtained at a speed 7.5 miles per hour higher than for the DC-4, or an increase in surface area of 22 percent.

Since the landing speed decreases with reduction in weight, it is realized that there is a limiting minimum weight at which full control will be available to the stall. This relation is illustrated for the DC-4 and similar two-engine airplane in Fig. 18. Representative areas are shown of weights below which the yawing moment from the rudder is less than the yawing moment from the engine.

Unless vertical surfaces are to reach enormous proportions, the minimum flying speed should increase approximately as the square root of the power weight ratio, and be about 22 percent larger for two-engine airplanes. The problem of control in an emergency at low speed is one of great importance, and take-off and

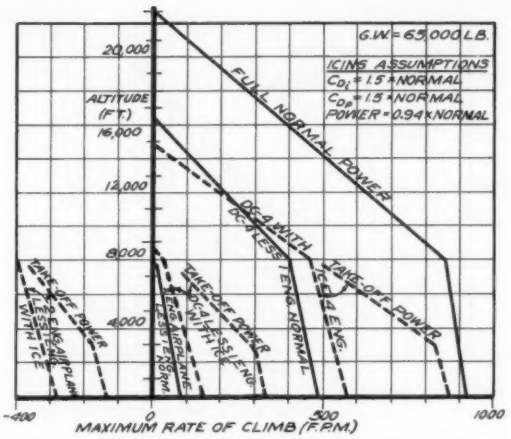

FIG. 19. Rate of Climb of the DC-4 in normal standard conditions and with moderately severe load of ice. Comparison is given with a similar two-engine airplane. DC-4 data is based on flight test results at 60,000 pounds.

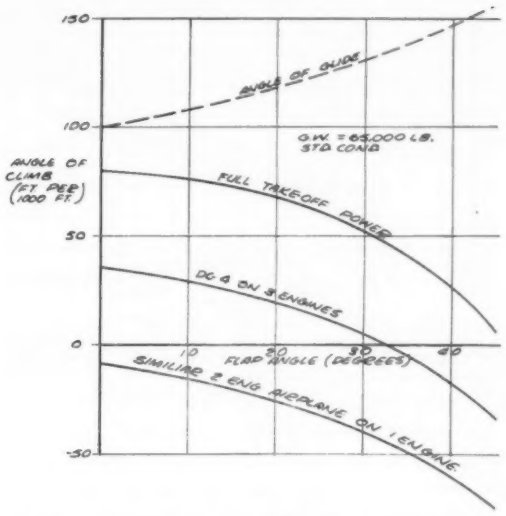

FIG. 20. Angle of climb of the DC-4 and a similar two-engine airplane, both with moderately severe loads of ice.

landing safety cannot be obtained without some margin of directional control. It is here apparent that the landing and take-off at higher speeds will be under better control in an emergency, and quite probably be safer than the same carried out at the absolute minimum operating speeds which normal requirements call for.

ADVERSE OPERATING CONDITIONS

It is customary to obtain flight performance of airplanes under ideal conditions and to reduce the results to standard altitude, weight, and power conditions. This is reasonable from the standpoint of establishing and meeting guarantees, and for comparison with other airplanes.

It is seldom, however, that the airplane will actually perform to 100 per cent of the ideal, because of many factors.

(1) In actual service operation the engine power output is not that of a new engine as used in initial tests.

(2) The temperature often reaches values above the standard, particularly at high altitudes, so that both power and performance of the airplane is considerably reduced.

(3) Sea-level take-off and landing performance are good and generally quoted, while altitude performance is seldom mentioned. For this reason the normal reduction in performance at the higher airports might be inadequate for safe operation.

(4) The airplane cannot always be piloted at exactly the ideal speed, altitude, etc.; so that even under standard conditions, a pilot might normally have some difficulty in achieving maximum performance.

(5) The airplane is often called upon to fly under quite adverse conditions; for example, as when operating with a load of ice. In this condition, the airplane suffers seriously throughout. The maximum lift coefficient is considerably reduced. The drag of the airplane will be markedly increased. Power will be reduced because of faulty engine operation or the necessity of using heated carburetor air. If any load of ice remains on the airplane, the weight of the airplane will be increased.

ICING

It is obvious that icing represents a severe handicap upon the performance of the airplane since it reduces the efficiency of all factors. Fortunately, propeller deicing is now quite satisfactory and the propeller efficiency holds up well. All major airlines, which operate continuously throughout the year, must have reserve to handle the airplane safely in these icing conditions. For this reason, the probable performance of the DC-4 has been investigated for such operations.

Tests which simulated moderately severe icing, where irregular ridges of ice remain sticking to the leading edge of the wing, showed that it is quite possible for the maximum lift to decrease 0.5 (33 percent flaps up and 23 percent flaps full down); the parasite drag area to increase 50 percent; and the induced drag to increase 50 per cent. In addition to these changes it is assumed that the power is reduced 6 percent by the application of heat to the carburetor (90°F. at 8,000 ft.) or by faulty engine operation.

The piloting personnel are especially concerned over the performance of an airplane after power plant failure when operating under icing conditions. Climbing performance of the DC-4 is shown in Fig. 19. It is especially noticeable that with icing the considerable rate of climb of three engines has been reduced to an amount giving only small reserve. The two-engine airplane for comparison can no longer maintain flight on one engine even on take-off power.

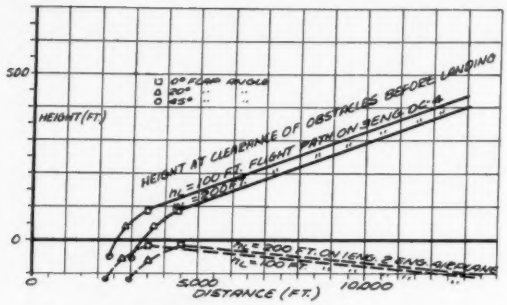

FIG. 21. Landing safety paths of the DC-4 and a similar two-engine airplane after engine failure with moderately severe load of ice. Gross weight = 65,000 lb.; airport elevation, sea level; standard conditions; no wind.

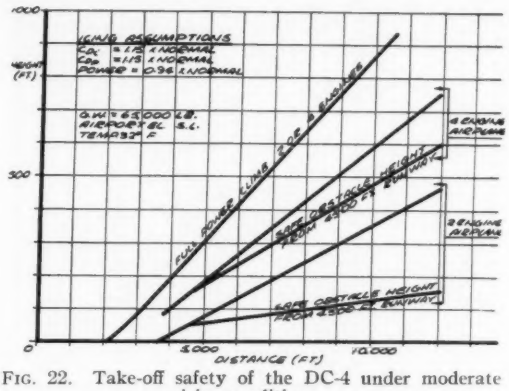

FIG. 22. Take-off safety of the DC-4 under moderate icing conditions.

Similarly, landing safety operations with the airplane flying under icing conditions are shown in Fig. 20, which shows angle of climb versus flap angle, and Fig. 21 which illustrates the landing safety operation. It is quite probable that the landing will often have to be made with a load of ice in snow or hail, where the performance is poor. It is quite necessary then that, in landing, the airplane have a high degree of emergency performance and good stability.

It is not probable that the airplane will take off under these extreme conditions, therefore, for the take-off safety operation the drags are increased only 15 percent and maximum lift decreased .15 (10 percent), as illustrated in Fig. 22.

Flying through icing or similar adverse conditions, therefore, requires greater margin of emergency performance than standard performance tests would indicate. Due to its large reserve power after engine failure the four-engine airplane can safely operate in such conditions when highly loaded. With the two-engine airplane, loading would have to be limited to compensate for the lower reserve power.

Book Review

Breathe Freely! The Truth about Poison Gas, by JAMES KENDALL; D. Appleton-Century Company, Inc., New York, 1938; 179 pages, $1.50.

Writers on the use of poison gas in warfare express a wide range of opinion. In some newspapers and popular magazines the horrors of the Great War are used as a basis to extrapolate a curve which leads to imaginary conclusions that civil populations will be exterminated by new mysterious chemical discoveries. Next come the informed military and aeronautical specialists who sincerely believe that gas may play an important role in the next war. Following these are the gas defense experts and chemists who are attempting to allay the fears which have been aroused by the first group. At the bottom of the scale are those who have so-called pacifist leanings and are relying on international agreements to prevent such attacks from ocurring.

Professor Kendall is one of the most famous British chemists. He has been a professor at Columbia, New York, and several other American Universities. Since 1928 he has been at the University of Edinburgh. In this book he aims to convince the average citizen that there is no need for panic when poison gas is used against civilians. He examines the whole subject from every possible angle and concludes that "it is exceedingly improbable that any inhabitant of Great Britain will actually undergo a gas attack, except after a heavy meal."

He examines the claims of the panic-mongers who envisage the extermination of civilians by gas bombs dropped by enormous air fleets. He discusses the use of gas during the War and gives figures to show that it was greatly over-rated as an offensive and defensive weapon. He flatly denies the existence of any super-gas which will do what the sensational writers claim for it.

As the book is intended to calm the fears of British readers he tells them how to protect themselves in case an enemy should be rash enough to employ gas in any future attack on England. He makes an interesting comparison. Poison gas killed less than five and injured less than 120 British soldiers every day during the time of its use in the War. The automobile kills more than sixteen and injures nearly 550 British men, women, and children every day in peace time. The author agrees with General Ashmore, who advised: "If you dash down into the Tubes at the mere threat of an air raid, then, to be logical, you should climb a tree every time you see a motor bus."

Professor Kendall writes in such a readable and interesting manner that he is able to present technical and tragic details without making them boresome or horrifying. While other experts may disagree with some of the conclusions they will have to admit that the book will serve a useful purpose by showing any aggressor that the country starting this form of warfare will suffer retaliatory attacks which will have serious results particularly on international morality.

A Terrain Clearance Indicator

LLOYD ESPENSCHIED and R. C. NEWHOUSE, *Bell Telephone Laboratories*

Presented at the Air Transport Meeting of the I. Ae. S., Chicago
November 19, 1938

Introduction

THE problem of an altimeter for aviation has engaged the attention of many inventors and experimenters for twenty years or more. As a result, about every conceivable fundamental method of attacking the problem, by the utilization of acoustic or electric phenomena, is disclosed in the art, including the many U.S. patents on the subject.

The familiar aneroid altimeter has reached a high degree of perfection and enables the pilot to maintain level flight at any desired altitude, but it gives no clue as to the variation of the elevation of the terrain beneath. The pilot has to know his position at all times and perform a mental calculation, in order to know his height above the ground at any given moment. A number of airplanes have drifted off their normal courses and have crashed on higher ground.

An altimeter based upon the use of a sound echo is subject to two fundamental limitations. The first is the extremely high noise level produced by the airplane's motors and propellers, which tends to submerge the relatively weak echo at heights of more than a few hundred feet. The second is that the speed of sound is not enough greater than the speed of airplanes. At a height of 1000 feet approximately 2 seconds are required for a sound to travel to the ground and return. In this time interval a modern airplane would travel 600 feet and the clearance may have changed materially.

There is in radio the corresponding phenomenon of an echo, an electric-wave reflection. The velocity of a radio signal is so great that an echo from the earth's surface is almost instantaneous. For instance, for heights less than 1000 feet the time to be measured is less than 2 millionths of 1 second.

The method used in the present instrument is extremely simple in theory. A radio transmitter is provided on the airplane which sends toward the earth a signal, the *frequency* of which changes at a definite rate with respect to time. The signal is reflected by the earth and returns as an echo after a time delay equal to twice the height, divided by the velocity of propagation. During this interval the frequency of the transmitter has changed and now differs from that of the echo by an amount equal to the product of the rate of change of frequency and the time of transit. The reflected wave is combined in the plane receiver with some of the outgoing wave energy and the difference or "beat" frequency is measured by a frequency meter. Since the reading of the meter is that of the "beat" frequency, it is proportional to the time delay of the echo and, hence, to height and thus can be calibrated directly in feet.

Early Efforts

The evolution of this method is interesting because it illustrates how one art is built upon another, and also the familiar story of separate inventors arriving at the same answer almost simultaneously, actually somewhat in advance of the existence of instrumentalities having the characteristics required to make the invention practically serviceable.

Many systems employing electromagnetic waves for the purpose of indicating altitudes of an aircraft have been proposed.[1] Among early workers in this field who independently of each other were concerned with methods involving frequency-modulated waves were J. O. Bentley,[2] of the General Electric Company, W. L. Everitt,[3] of Ohio State University, and certain students in his department of Electrical Engineering including the junior author[4] and M. W. Hively, and the senior author.

Under the direction of W. L. Everitt some experimental work on the frequency-modulation method, using wire lines, was undertaken in the school year 1928–1929. On the basis of this work a grant was made by the Guggenheim Fund for the promotion of aeronautics and an investigation was continued with experimental tests during the following school year under the auspices of the Ohio State Engineering Experiment Station. The experiments were reported upon in the bulletins of the Station and in a graduate thesis[5] of the junior author and J. D. Corley.

As early as 1920 the senior author proposed the use of electric-wave reflection in railway safety systems[6] and entertained the idea of frequency-modulated transmission with beat-tone detection for measuring distance along a track. Radio-wave reflection for aircraft altitude determination was considered at times from 1926 to 1930 when a patent application was filed[7] for an arrangement similar to that which has been worked out, including the use of a frequency meter to give continuously a visual indication of the altitude.

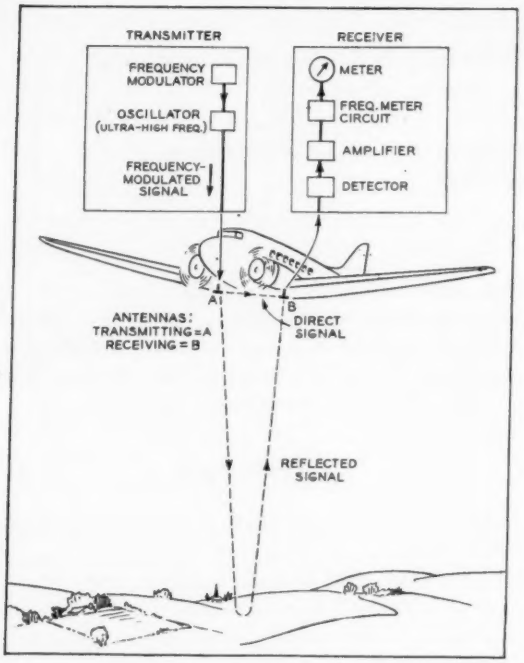

FIG. 1. Overall system.

At that time, however, a really practical terrain clearance indicator could not be built due in large part to the lack of suitable radio instrumentalities. Vacuum tubes capable of operating on frequencies approximately fifty times higher than those generally available were indicated as necessary before a satisfactory system could be built.

A long-range program, however, of vacuum-tube development for high frequencies was under way in Bell Telephone Laboratories. This resulted in the production of suitable tubes and they were described by A. L. Samuel[8] to the Institute of Radio Engineers in October, 1937. One of these was capable of providing a stable output of between 5 and 10 watts at a frequency of approximately 500 megacycles, so it became feasible to undertake the development of a practical terrain clearance meter.

The Japanese have been experimenting recently with apparatus operating upon the same basic theory and a paper[9] was published in Japanese in 1936. A later paper[10] was published in English in 1938 by the same author which describes the apparatus and the results of tests made on the ground over short distances with the equipment at rest.

Technical Problems

At the time this development was undertaken a number of questions presented themselves as to what the earth's surface would do to the incident wave in reflecting it. It seemed possible that the signal might be so scattered and broken in reflection by small irregularities that the echo would be more like static than a useful signal.

Even if the reflected signal proved satisfactory over the smoother surfaces, it was hard to predict what would happen when flying over timber land or over very irregular mountainous terrain. There was also the question of what would happen when the surface happened to be that of a city.

Several problems were anticipated in the apparatus itself. The theory is based upon a frequency-modulated signal free from any amplitude modulation, and it was questioned whether a transmitter could be built to operate on ultra-high frequencies which would be sufficiently free from amplitude modulation, when subjected to the vibration of the airplane, to be satisfactory. Since the receiver utilizes both the direct and reflected signals in making the altitude measurement, it is necessary that some signal be picked up directly from the transmitting antenna but not enough to overload the receiver and thus prevent reception of the echo. It was expected that difficulty would be encountered in sufficiently reducing the direct signal.

After considering all these problems, it was decided that the cheapest and easiest way of determining the answers was to build the apparatus and try it out to see if correct operation could be obtained, first, under the more or less ideal conditions of flying over smooth water and, then, over less favorable surfaces.

Most of the measuring equipment available for radio-frequency test work is useless at ultra-high frequencies. Hence, it was necessary to get the system functioning as a whole before any means were available for determining the best adjustment of the radio-frequency parts of the system. Because of the difficulty of providing, while on the ground, an adequate reflector at distances of from a few feet to thousands of feet from the apparatus, it was necessary to install the equipment in an airplane very early in the development and make most of the tests during flights. Nearly a hundred airplane flights were made in one of the Bell Telephone Laboratories' airplanes during the development period of seven months which preceded the public demonstrations made in the United Air Lines Flight Research Airplane.

Operation and Theory

The fundamental parts of the altimeter in relation to their application are shown in Fig. 1. An ultra-high frequency oscillator is provided, whose frequency is varied up and down by a modulator which consists of a small, rotating, variable condenser driven by a motor. The oscillator is connected through a coaxial transmission line to a transmitting antenna which is located on one of the lower surfaces of the airplane. The signal is radiated downward by this antenna. A radio receiver is connected through a similar coaxial line to a second antenna similarly located but arranged in such

a way that a minimum of direct signal is received from the transmitting antenna and as much echo as possible from the ground. The direct and reflected signals are applied to a detector circuit in the receiver. The output of this detector is a signal of a frequency equal to the instantaneous difference existing between the direct and the reflected signals and is proportional to the height of the plane above the terrain. This signal is amplified by the receiver and applied to a frequency meter or counter circuit which is so designed that a current proportional to the frequency and, hence, to the height flows through a meter calibrated in feet and located on the airplane's instrument panel. A number of types of indicating frequency-meter circuits[11] of the condenser charge and discharge variety have been described in the technical literature.

The operation of the system can be understood more easily by reference to Fig. 2. The variation of the transmitter frequency with time is indicated by the solid-sawtooth line.* The value of the ordinate of this curve at any point is the transmitter frequency for the corresponding time. The frequency is varied from $F_{min.}$ up to $F_{max.}$ and back F_m times per second, so the rate of change of frequency is $2\Delta F F_m$ when ΔF is substituted for $F_{max.} - F_{min.}$. The linear frequency variation shown, while ideal, is not essential for the successful functioning of the apparatus. The dashed-sawtooth line represents the variation with time of the frequency of the echo signal from the earth's surface. This curve is displaced to the right by a time equal to twice the height divided by the velocity of propagation or, in other words, the time it took the radio signal to go down to the earth and return. This results in a frequency difference between the direct and reflected signals which is equal to the product of the time delay $2H/C$ and the rate of change of frequency, and is given by the equation,

$$F_d = 4\Delta F F_m H/C \text{ cycles per second}$$

The difference is plotted again at the bottom of the diagram and appears as a series of trapezoids of height F_d. The time delay, $2H/C$, has been greatly exaggerated in comparison with $1/F_m$, the time interval corresponding to one cycle of frequency modulation, in order to make the difference, F_d, large enough to show on the diagram. F_d is actually only a few cycles in hundreds of millions. It will be noted that F_d drops momentarily to zero twice for each complete sawtooth variation of the transmitter frequency. This is due to the necessity of varying the transmitter frequency, first, up and, then, down, instead of forever in one direction.

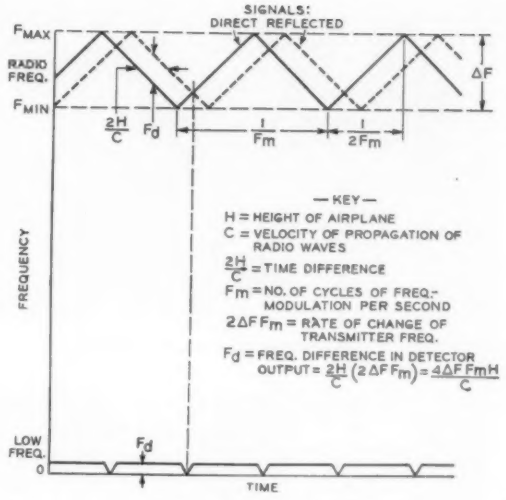

FIG. 2. Operating theory.

Hence, the theory must be considered from the standpoint that one altitude measurement is made for each upward and another for each downward sweep, ΔF, of transmitter frequency so that a total of $2F_m$ measurements are made per second. The number of cycles of frequency F_d, occurring during one frequency sweep, is,

$$F_s = F_d \times 1/2F_m = 2\Delta F H/C$$

since $1/2F_m$ is the time of one sweep, ΔF. F_s is directly proportional to both the height and to the amount of transmitter frequency change, ΔF.

The fact that $2F_m$ separate measurements are made per second is important only when considering small altitudes. The height which gives a value of unity for F_s corresponding to a frequency-meter signal of $2F_m$ cycles per second is the minimum height which can be indicated since lower altitudes give the same reading. Lower altitudes cause only a fraction of a cycle of frequency, F_d, to be generated per sweep, but since this fraction is repeated $2F_m$ times per second, it constitutes a signal of the same frequency, $2F_m$, and is so counted by the frequency meter. In order to make this minimum altitude small, it is necessary that ΔF be large, since they are inversely proportional to each other. A frequency sweep of approximately 25 megacycles is required to provide measurements down to the present minimum of about 20 feet. If a high antenna efficiency is to be obtained over a band 25 megacycles wide, it is necessary that the percentage variation from the average frequency during the modulation cycle be small. This percentage variation is made small by the use of an average frequency of approximately 450 megacycles. The use of this ultra-high frequency has the additional advantage that the antennas can be both small and efficient and cause little drag upon the airplane.

* A simple harmonic wave that changes in frequency from instant to instant is no longer a single frequency but a series of discrete frequency components. In the present instance, the number of cycles of frequency modulation per second is small compared to the transmitter frequency swing, so the spectrum occupied by the signal is substantially that of the swing itself.

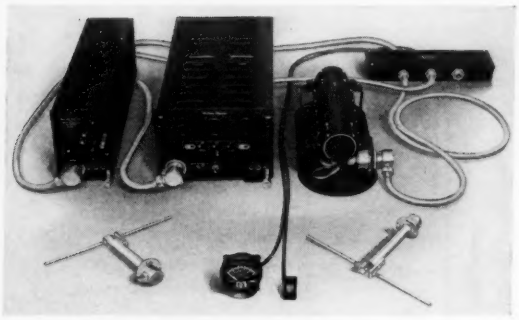

FIG. 3. Terrain clearance indicator units.

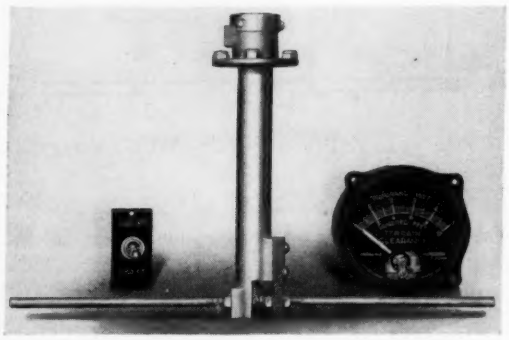

FIG. 4. Antenna, meter, and range switch.

APPARATUS

Fig. 3 is a photograph of all the units of the altimeter, with the exception of the transmission lines used to connect the antennas to their respective units. The units are as follows, left to right: receiver, power unit, and transmitter, with a junction box in the upper right. In the foreground are the two dipole antennas and the indicating meter with its range-shift switch. The meter and one of these antennas are shown in larger scale in Fig. 4. The meter has two scales, the upper extending from 0 to 5000 feet and the lower, 0 to 1000 feet. The position of the range switch determines the scale to be used in reading the meter.

Fig. 5 shows an assembly of the various units located approximately as they would be installed in an air transport. The transmitter, power unit, receiver, and a junction box are installed in the baggage compartment just aft of the cockpit with cable connections to the airplane battery and to the meter and range switch on the instrument panel. The transmitting antenna is shown below the wing to the left of the engine nacelle and the receiving antenna to the right of the other engine nacelle. Coaxial transmission lines connecting the antennas to the transmitter and receiver, respectively, are indicated by the lines extending through the wings from the antennas. It was necessary to exaggerate the size of some of the units in order to make them large enough to see in the diagram.

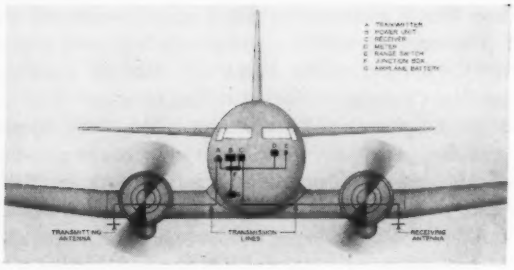

FIG. 5. Airplane installation.

The installation with apparatus as pictured in Fig. 3 weighs complete with all cables and connections about 70 pounds. Since the equipment shown in the pictures represents a working model built with the idea of attaining performance, rather than minimum weight, undoubtedly some reduction in weight will be obtained in future models.

The antenna installation shown, utilizing half-wave, dipole-type antennas approximately a quarter wave length below the reflecting surface of the wing, is not particularly directional. The signal is radiated over approximately the whole hemisphere below the wing centered on the transmitting antenna. The strength of the signal is greatest in the downward direction but does not fall off rapidly in other directions. The advantage of this antenna arrangement is that the distance to the nearest reflecting surface is measured regardless of whether it is directly beneath, or to the front or side. As a result, very little change in reading occurs when the airplane banks steeply. Some advance indication also is given when the airplane in level flight approaches higher terrain.

PERFORMANCE

The terrain clearance indicator in its present experimental form indicates altitudes between approximately 20 and 5000 feet. When over smooth water or land, it is subject to errors as indicated by a consideration of the fundamental equation upon which the altimeter is based,

$$F_d = 4\Delta F\, F_m\, H/C$$

Since F_d is directly proportional to both ΔF and F_m, any variation of a given percentage in either will result in a corresponding percentage error in the reading of the meter. It is believed from the data available that the errors due to variation of either ΔF or F_m do not exceed ± 1 percent.

Additional errors can also occur in the frequency-meter circuit. These errors are believed to be less than ± 7 per cent, so that a total error of ± 9 percent might occur if all the errors were simultaneously in the same direction. Fortunately, all these are of a percentage nature, so that the error in feet becomes smaller as the ground is approached. An absolute error in the indi-

cation is still possible because of the limitations of the milliammeter used on the instrument panel. The Weston aircraft meter used is guaranteed to be correct to within 1 percent of its full scale reading at any point on its scale which permits maximum errors of 10 feet on the 1000-foot scale and 50 feet on the 5000-foot scale.

When flying over rough water, wooded terrain or cities, the reflected signal is received from surfaces at different distances simultaneously, resulting in addition and subtraction interference effects, thus sometimes momentarily reducing the echo signal below the minimum required for accurate indication. In such a case, the meter hand may swing down momentarily as much as 10 percent. For the present limited transmitter power and receiver sensitivity, at altitudes above 2500 feet, these momentary signal reduction effects become progressively more serious when flying over irregular surfaces so that for a substantial part of the total time the echo signal may be below the minimum required for correct meter reading. This is indicated by a reading fluctuating between 3000 and 5000 feet when flying at 5000 feet over a surface dotted by buildings, timber, etc. The meter swings up to the correct reading every time the airplane passes over a smooth field or body of water of any size. Up to 2500 feet the echo signal has proved to be sufficient for steady operation over all kinds of terrains.

Tests have been made over New York, Raritan, Newark, and San Francisco Bays, Great Salt Lake, Lakes Erie and Michigan, the timbered mountains of Washington and Oregon, the deserts and mountains of the southwest, and the cultivated areas of the midwest during the period of the recent demonstration flights made with the equipment installed in the United Air Lines Flight Research Airplane.

An indication of the character of the surface over which the airplane is flying is given by the variations in the meter reading. A city usually causes rapid fluctuations of the order of 50 feet, depending, of course, upon the height and the spacing of the buildings. Cultivated farmland causes fluctuations of lower frequency and amplitude. An isolated, high object such as a skyscraper or a chimney is indicated only by a slight meter kick as the airplane passes over it, which may not be noticed by the observer. If the airplane passes over only a few feet above the object and the top is large enough to contribute momentarily most of the echo signal received by the airplane, the indication is unmistakable and the correct distance to the object is indicated by the meter. For instance, the gas-storage tank near the Chicago airport is an excellent object upon which to demonstrate the altimeter performance. The instrument is useful as a position indicator when approaching an airport on a course which crosses an obstruction of appreciable height and size since the moment of passage over the obstruction is clearly indicated. In fact, use as a position indicator may be one of the altimeter's most valuable applications.

A study of the circumstances in connection with a number of crashes in the west during recent years has revealed that in most of the cases the airplanes crashed after having been within a few feet of the ground without the pilots knowing it for several minutes before they struck. In such a situation the terrain clearance indicator should be capable of warning the pilot in ample time to avert a crash.

The writers wish to express their appreciation of the contributions of a number of other members of the technical staff of the Bell Telephone Laboratories to the success of this project.

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Aerodynamic Research at the National Physical Laboratory

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Presented at the Meeting of the Los Angeles Branch of the I. Ae. S.
September 30, 1938

Introduction and Brief History

THE National Physical Laboratory was founded in 1900 for the purpose of carrying out research in the physical sciences, and in particular for the establishment of precise standards and for the testing of apparatus and materials. The scientific control was first in the hands of the Royal Society of London, but in 1918 the institution had become so large and of so national a character that it was made a part of the newly created State Department of Scientific and Industrial Research. The Royal Society, however, continues to advise on the scientific aspects of the work.

Research in aerodynamics was started in 1909, by a small section of the staff of the Engineering Department, then under the superintendence of the late Sir Thomas Stanton and under the immediate control of L. Bairstow. The development of flying since that time is reflected by the growth in the size and importance of this group of workers, a development which was so accelerated during the war period that in 1917 a new Department of Aerodynamics was created under Mr. Bairstow. It was again directed by Sir Thomas Stanton when Bairstow left to take up his professional appointment in London, and subsequently by R. V. Southwell and by the author (since 1925).

At the same time, aerodynamic research, was also being conducted at the Royal Aircraft Establishment, at Farnborough, particularly with reference to actual flight tests, for which no facilities were available at Teddington. This Establishment is under the direct control of the Air Ministry. The two institutions have developed along parallel lines, and have always maintained a very close cooperation.

The aerodynamic work at the N.P.L. has, since the beginning, been governed by a special Committee, known first as the Advisory Committee for Aeronautics and later as the Aeronautical Research Committee. This Committee also considers the program of research at the Royal Aircraft Establishment and other Air Ministry Stations and advises thereon. The coordination, both through the Committee, and directly among the workers, has been found sufficient to prevent serious overlapping of effort, and it is often a great advantage to have two separate groups of scientists thinking independently about the problems which arise.

Equipment at the N.P.L.

Atmospheric Wind Tunnels

A good deal of the wind-tunnel equipment of the Laboratory dates from the period of the great war, in fact, the original 4 ft. tunnel built in 1911 is still in use. There is another similar 4 ft. tunnel and two 7 ft. square in section belonging to this period, as well as the so-called "Duplex" tunnel, which is 7 ft. high but 14 ft. wide. All these tunnels are of the old N.P.L. type in which the air is sucked in through a bell-mouth and a honeycomb at one end and discharged into the room through a series of graded holes in the sides of the duct behind the airscrew. They have the disadvantage of a low power factor (about 0.6) but the advantage that it is easy to secure very good velocity distribution at the working section. Their speeds are low, judged from a modern standpoint, being between 70 and 100 ft. per sec. Their turbulence depends on the distance of the working section from the honeycomb, and the critical sphere number is about 150,000 in the 4 ft. tunnels, 180,000 in the 7 ft., and 230,000 in the Duplex. There was a third 7 ft. tunnel, but in 1934 this was replaced by two open jet return flow tunnels having elliptical jets 9 ft. $\times$ 7 ft. and double return ducts above and below the jets. These two tunnels are identical and have a top speed of 210 ft. per sec. with motors of 300 hp. The power factor is about 2.6. The seven tunnels above mentioned complete the equipment of atmospheric tunnels at present in use, but two new ones are being constructed. One of these is a modern version of the Duplex tunnel, whose size has been found very convenient for tests of complete model aircraft with running airscrews. This new tunnel will have a closed working section 13 ft. $\times$ 9 ft. (rectangular with rounded corners) and the speed will be about 250 ft. per sec. It will be of the now almost standardized type with a single return duct, but will differ from the majority of tunnels in that it will have a fine honeycomb and a settling chamber before the contracting jet, with the idea of reducing the turbulence to a low value. The second new tunnel is of a special type designed for researches on turbulence along the lines of a small tunnel of that kind which has been developed at Cambridge University. It will be 7 ft. in diameter and capable of

speeds between 100 and 150 ft. per sec. Its special features are a very fine honeycomb, a long settling chamber, a large contraction ratio to help in securing low turbulence, and a long working section to enable the decay of turbulence to be studied.

The Compressed Air Tunnel

Present equipment of special type is represented by the Compressed Air Tunnel, completed in 1933. This tunnel has a circular open jet 6 ft in diameter and is capable of speeds up to 90 ft. per sec. at 25 atmospheres pressure. Under these conditions a test Reynolds Number of 8×10^6 is reached with 8-inch chord airfoils. The containing shell is built up of four rings rolled each from a single ingot and joined together by external straps. The hemispherical ends are each formed of two steel castings. The diameter of the cylindrical part of the shell is 17 ft., the thickness of the metal $2^3/_8$ in., and the weight of the whole tunnel is over 300 tons. The balances are operated from a control table in the tunnel room, and work on the same principle as the Kelvin current balance, the aerodynamic reactions being balanced by the electromagnetic attraction of air-cored coils of wire, and the forces thus measured in terms of the current. Electrical devices of various kinds are used to set and indicate the angle of incidence, and to indicate when the balance is in equilibrium etc. This equipment, which is entirely electrical, and does not involve being able to see the model through windows in the tunnel, has given very little trouble indeed in five years of running.

In carrying out the design and construction of this tunnel and its associated apparatus, the author found the previous experience gained on the V.D.T. at Langley Field exceedingly helpful.

High Speed Tunnels

In 1935 a high speed tunnel, 1 ft. in diameter, was installed, using the exhaust air from the compressed air tunnel as a source of energy, very much as had previously been done at Langley Field. It is becoming evident that in the near future problems of the effects of compressibility at high speeds will become vital to the designer of aircraft, and steps are now being taken to build a second and larger high speed tunnel, designed mainly for photograpic work on high speed flow. The two tunnels will be placed in a new building close to the compressed air tunnel, and some additional air reservoirs will be provided so that they can be used independently of the supply of exhaust air from that tunnel. There will also be some space left for the future development of high speed equipment.

Whirling Arm

There is one piece of equipment which seems peculiar to the N.P.L. among aeronautical laboratories. This is the Whirling Arm, which was erected before any of the tunnels and has been modified and in continuous use ever since. It has a radius of 30 ft. and a speed of about 60 ft. per sec. can be attained. The original whirling arm was used to calibrate the first standard pitot-static tube, on which all the wind speed measurements in the Laboratory depend. The Arm was rebuilt later to make it suitable for the measurement of forces and moments on aircraft models during a steady turn, and it is for such experiments that it has since been used. It is difficult to imagine a complete study of lateral stability without the use of a whirling arm to determine the derivatives depending on rate of yaw. The Laboratory is about to build a new whirling arm of greater strength and stiffness than the old one, in order that stability experiments can be carried out with the added complication of the slipstream. The present Arm is not strong or stiff enough to support other than very light models and could not be used for one containing a motor to drive the airscrew.

The Research Work of the Department

By far the greatest part of the work of the Aerodynamics Department is general research directed toward the solution of problems of flight. This work is financed by the Air Ministry, and discussed, as already mentioned, by the Aeronautical Research Committee. In addition a number of tests of an *ad hoc* nature, particularly in relation to the development of new aircraft, are made directly for the Air Ministry. If, however, such tests reveal new points of fundamental interest, they are often referred later to the Research Committee, and their relation to the general research program is discussed.

Fundamental Problems of Fluid Flow

It may be said of any science that an advance of knowledge of the fundamental principles inevitably leads to progress in the application of the science to practice. The position in aerodynamic science is rendered more difficult than in many other fields by the extremely complex nature of the fundamental theory. The N.P.L. has been fortunate in being able to keep a small number of scientists engaged upon such fundamental problems even at periods such as the present, when the pressure of more immediately practical problems is almost overwhelming. From the beginning much attention has been given to the visualization of flow, in order to learn the detailed nature of the phenomena which had to be explained. The beautiful results achieved in recent years by Fage with the ultramicroscope and Townend with tiny spots of heated air produced by electric sparks, illustrate the development of this line of research. These methods have been used not only to study the general nature of the flow round bodies, but also for such detailed work as the investigation of the nature of turbulent motion. The Laboratory

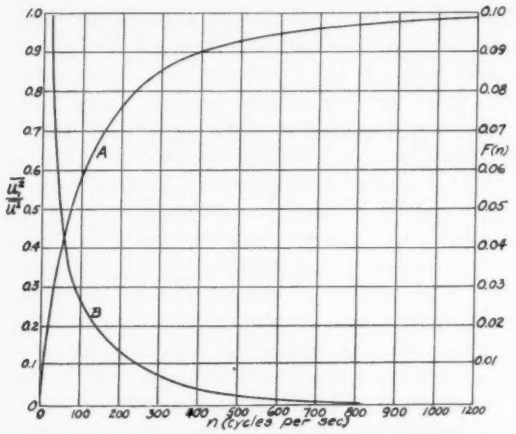

FIG. 1. Spectrum of turbulence. Curve A gives the fraction of the total turbulent energy contained in the frequency range 0 to n. Curve B gives the distribution of energy over the frequency range, $F(n)$. The ordinate is such that $\int_0^\infty F(n)dn = 1$.

is, at the moment, profoundly interested in turbulence and its effects, both from the fundamental point of view, and because of its importance in the practical interpretation of many model experiments. In this connection, the work being done under the guidance of Prof. Prandtl and Prof. von Kármán is watched with the greatest interest. Those who work on these problems at the N.P.L. have been fortunate in the close cooperation with Prof. G. I. Taylor, of Cambridge University, whose theoretical work on the subject has attracted such great interest. Recent work at the Laboratory has been chiefly directed to the study of the detailed structure of turbulent motion by means of fine hot wire anemometers, on similar lines to the excellent work of Dr. Dryden at Washington. Both the turbulent fluctuations at a point and the correlation between the fluctuations at neighboring points, in this case by the simultaneous use of two hot wires, have been measured. In addition, the distribution of turbulent energy over a range of frequency (Fig. 1), by the use of a hot wire associated with amplifier and filter circuits has been explored. Many of the experimental results are in close agreement with Taylor's theoretical work when the turbulence is isotropic. This turbulence research is an example of a fundamental study whose connection with practice is not yet clear. It is known that turbulence produces marked effects on certain aerodynamic phenomena and a more detailed knowledge of turbulence should lead ultimately to an explanation of these effects. There is a good deal of work going on in England on the theory of flow, and particularly boundary layer flow. Most of this work is at the various Universities of the country. If such theoretical work leads to more knowledge of the effect of disturbances on the stability of fluid flow, it may well provide the link between the disturbances present in turbulent flow and their effects on aerodynamic forces.

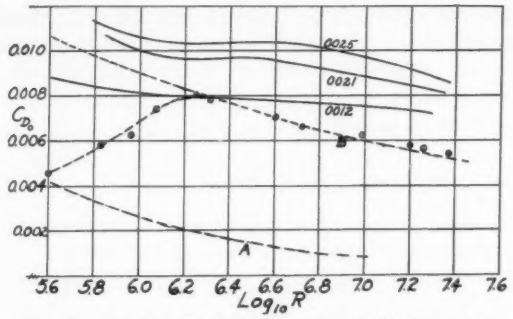

FIG. 2. Drag of airfoils in Compressed Air Tunnel by pitot traverse. Curve A gives the drag of a flat plate when the boundary layer is laminar. Curve B gives the drag coefficient of a flat plate when the boundary layer is completely turbulent. The experimental points were measured in the Compressed Air Tunnel. Curves for the N.A.C.A. airfoils 0012, 0021, and 0025 are also given.

Performance of Aircraft

In these days, when aircraft engineers are striving for the highest possible performance, the question of reducing drag to the minimum possible is one of great practical importance. It is interesting, in passing, to remark that only in the last year or so have reliable measurements of the value of the profile drag of wings in flight been available. This has been accomplished through B. M. Jones's masterly refinement and application of the Betz-Schrenk method of drag determination from a traverse of the wake with pitot and static tubes. This powerful method of drag measurement has also been applied in the Compressed Air Tunnel, and has enabled very much larger chord airfoils to be used at low lift coefficients. It has been possible to extend the range of Reynolds Numbers from about 8×10^6 on the standard airfoils used in balance tests to about 24×10^6, which is certainly by far the largest value yet reached in wind-tunnel tests. The Laboratory has found that at Reynolds Numbers above 10^7 the drag curves of all smooth airfoils so tested run very nearly parallel to the turbulent skin friction curve of a flat plate, but lie above the flat plate curve by amounts which increase with the thickness of the aerofoil (Fig. 2). The staff is at present engaged in a complete drag analysis of two such large-chord airfoils, respectively 12 per cent and 24 per cent thick, in order to discover how much of the excess drag over the flat plate value is due to extra skin friction over the curved surface, and how much to pressure reactions. In these experiments it is hoped that the hot wire anemometer technique can be used to locate the transition point, where turbulence in the boundary layer commences. This work will be done over the whole available range of Reynolds Number, and should provide invaluable data for comparison with results derived from boundary layer theories.

The drags of airfoils in the Compressed Air Tunnel are definitely higher than those measured in flight on smooth wings, and this is known to be due to the more forward transition point in the tunnel, caused by the

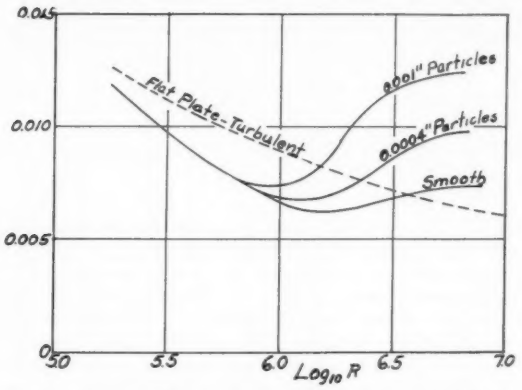

FIG. 3. Drag coefficient curves of the N.A.C.A. 0012 airfoil, aspect ratio 6, with various degrees of roughness.

tunnel turbulence. The difference can be calculated with sufficient precision for practical purposes if the two transition points are known. It is here that the difficulty occurs, for there are as yet no means except direct experiment of saying where the transition point will be on a wing in the free air, nor is it known whether the far-back transitions observed by Jones and others, as described in the first Wright Brothers Lecture, will be maintained at still higher Reynolds Numbers.

A very important matter is the effect of surface roughness on drag; this subject was treated in a paper by the author at the Fifth International Congress for Applied Mechanics at Cambridge. Suffice it to say that every attempt is being made to secure smoothness of construction, since experiments have amply demonstrated that it is worthwhile to do so. Fig. 3 gives typical results.

Work is being done on the problem of interference drag, and particularly on wing-nacelle interference, which is a very serious matter in the case of small high-powered aircraft. This is a problem which is very difficult to reduce to a systematic research, since the variations met with in practical design are so wide. An attempt is being made to attack it systematically, including the effect of slipstream, and also by tests to improve specific designs. The related question of engine cooling is also of great importance, but is not dealt with at the N.P.L., since a large enough tunnel is not available for this work.

Stability and Control

It is perhaps fair to claim that in the early days Britain led the way in the study of stability. Lanchester said much that few understood at the time, later on Bryan wrote down the stability equations for the airplane and Bairstow elaborated them. Bairstow and his collaborators, of whom the author had the good fortune to be one, were, it is believed the first to measure stability derivatives in the wind tunnel and to trace their consequences by the use of the theory. In the days of the biplane, stability was fairly well understood, and no unforeseen troubles were likely, except with respect to lateral stability near the stall. The almost universal change to the monoplane has altered the position greatly. There is, as yet, nothing like as much stability data available for the modern types as there was for the older biplane, though a concerted effort is being made to repair this defect. Moreover, the thicker-winged monoplane, particularly the low-wing type, has introduced more aerodynamic complication into the interaction of wing and tail surfaces, and this, together with larger slip-steam effects consequent on higher power, has made the subject an exceedingly complicated one. The N.P.L. recently attacked the problem systematically by model tests on a typical twin-engined monoplane. The first stage of this investigation has been completed but the results have not yet been fully analyzed or published, so the details cannot be given. It can be said, however, that the work has shed much light on the complex interactions of wing, tail, and slip streams, and has provided, at least in general terms, the explanation of some unexpected stability characteristics that had been observed in flight.

The question of stability near the stall, important in connection with safety during landing and take-off, continues to be investigated. By the use of short streamers the nature of the stall is observed, and by means of the rolling balance the magnitudes of the rolling and yawing couples involved are determined. The aim is to attain a form of wing design which will be free from all vice up to the stall, and through the stall if possible. Full scale experiments are also being made at Farnborough, since it is realized that this problem is one in which marked scale effects may be expected, and the model work must be approximate.

The question of the balancing of controls is under investigation. The attainment of close balance becomes increasingly difficult both as size and speed increase. The author feels, though without definite proof, that British pilots like controls which are lighter than those considered satisfactory elsewhere. Be this as it may, the laboratory is continually faced with the problem of producing better balances. The controls at present in use can be made to meet requirements, but they appear to be very critical in the matter of balance and sensitive to very small variations in the shape of the surfaces. It is felt that there must be some principle of aerodynamic balance which is better than those hitherto employed, and, in particular, which is susceptible to exact calculation and not critical to shape. It is to the discovery of such a balance that the present researches are directed.

Flutter Problems

Some years ago, flutter announced itself as a new danger in flight. By a theoretical study of the condi-

tions necessary for flutter to occur, interpreted numerically by the results of wind-tunnel experiments, it is possible to lay down a number of rules for the avoidance of flutter, the most important of which was the correct mass balancing of control surfaces. These measures removed the danger, and up to the present time no further trouble has been experienced. However, this happy state of affairs may not continue idefinitely as speeds of flight still further increase, and for this reason the N.P.L. is still pursuing the subject. One line of research concerns the more accurate application of existing theory, and involves the accumulation of a more detailed knowledge of flutter derivatives and of the effects of frequency and amplitude of oscillation on their values. Another line of research is the study of oscillations in systems obeying non-linear laws, the older theory being based on the usual assumptions made in problems of small oscillations that the forces involved are proportional to the displacements and velocities. It is, of course, well known that there are features in actual aircraft of a non-linear nature, such as, for example, the hinge moments of control surfaces and the presence of solid friction. It is not known how such non-linear behavior will affect the flutter problem, since, with increasing speed, the critical conditions are approached, nor how far it is possible to approach the ideal of the system that will not flutter at any speed even in the presence of these non-linear effects. It is for these reasons that the laboratory considers the flutter problem worthy of further study in spite of the absence of any immediate danger.

High Speed Research

The high speed tunnel at the N.P.L. and the intention to provide more facilities for work on aerodynamic phenomena at high but subsonic speeds have already been mentioned. The author is convinced that the next few years will see speeds of flight advance into the region where compressibility effects will have to be taken account of in design, and the Laboratory's aim is to learn something of the nature of these effects before the time comes to apply such knowledge to practice. Up to the present, the chief application of high speed data has been to the tip sections of airscrews, but with very little further speed increase the effects will be felt on the drag of wings and other parts of aircraft and particularly on thick wings. The lead given by Langley Field in determining the behavior of airfoils up to speeds nearly that of sound has been followed by the N.P.L. with the exception that more emphasis is laid on thick wings with an eye to the drag problems of the very fast machine of the future. The laboratory has, incidentally, successfully used the

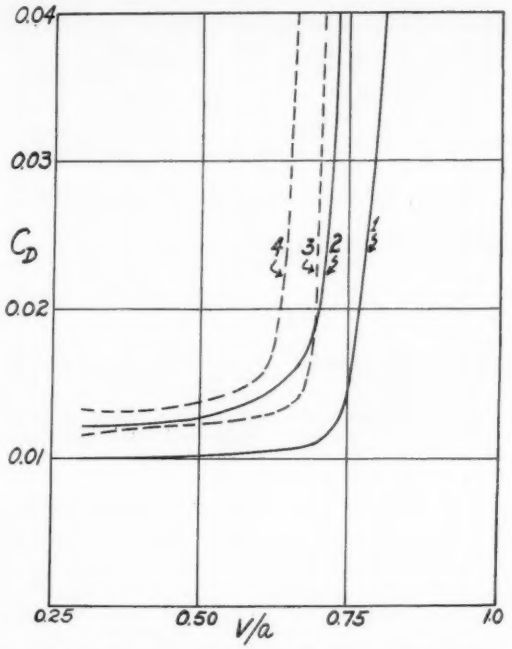

FIG. 4. Typical results, based on measurements by the pitot traverse method, showing the effect of compressibility on the drag coefficients of airfoils of various thicknesses. Curve 1 refers to the N.A.C.A. 0012 at 0°; curve 2 refers to the N.A.C.A. 0020 at 0°; curve 3 refers to the R.A.F. 69 (20.7 percent thick, 2 percent camber) at 0°; curve 4 refers to the R.A.F. 89 (25 percent thick, 2 percent camber) at 0°.

pitot traverse method of drag determination at these high speeds (Fig. 4), by a modification of the theory, and it has the advantage over force measurements that the nature of the wake gives an idea of the extent of the shock waves formed on the aerofoil. The staff has also been interested in the temperature changes, both in the air and on the surface of bodies, which occur in high speed flow, and sees in the measurement of temperatures at the surface a possible means of locating the development of a shock wave at any point. However, the work has not gone far enough yet to say definitely if this can be done.

Conclusion

It has only been possible to indicate some of the main problems that are engaging the attention of the N.P.L. at the moment, and only a very brief account even of these has been given. However, the author hopes he has succeeded in giving some kind of a picture of the Aerodynamics Department of the N.P.L. and its place in the aeronautical research of the world. In conclusion, a word of appreciation is in order for the help so often obtained, on many of the problems, from the researches carried out in America.

Constant Speed Control Theory

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(Received September 19, 1938)

SUMMARY

The general theory of the constant speed control is reviewed for an "error" and "rate-of-change of error" control applied to a system possessing inertia but no damping or inherent speed stability. It is shown that the most satisfactory control is one which has a high natural frequency, small inertia, and little or no Coulomb friction. Viscous damping is shown to have a less detrimental effect on the response of the control than control inertia, and the general conclusion is drawn that stability of the motion is secured by viscous damping in the control, while good performance is obtained by keeping the inertia of the control small.

INTRODUCTION

CONSTANT speed controls are applied to prime movers which are unstable in themselves. Examples are: the usual form of the steam engine; systems which operate most efficiently at some particular speed, as the engine-propeller combination of an airplane; and in general, systems for which constant speed is desired but which possess insufficient inherent stability against changes in the operating conditions.

When the control is linear, it applies a controlling torque proportional to the speed error. In a more refined form, the controlling torque is proportional both to the speed error and to the rate at which it is changing. This is typical of shaft governors for high speed engines and turbines.[1]

Since the usual flyball governor or its equivalent is not linear, it is necessary to assume small error changes. As it is the usual purpose of the control to keep the error small, this is a reasonable assumption. However, in applying the theory to an actual design, the control should be investigated for a number of cases, covering its whole operating range, as the system constants for a non-linear control set to maintain a low speed will differ from those of the same control when adjusted to maintain a higher speed.

IDEAL CONTROL

It is convenient to consider first an ideal control which acts instantaneously, and has no inertia, damping, or friction. The speed error will be determined when a disturbing torque L is suddenly applied to the controlled system. From the response to this suddenly applied torque, the response to any arbitrary forcing function can be obtained, if desired, by the superposition theorem of Boltzmann and Duhamel.[2] Let

U = speed error of controlled member (zero when the member has the desired speed)

I = inertia of controlled member referred to U

s_e = control sensitivity = controlling torque applied per unit error in speed.

For the ideal control a summation of torques gives

$$L - I\dot{U} - s_e U = 0 \tag{1}$$

from which the steady state error is by inspection

$$U_{ss} = L/s_e \tag{2}$$

and the motion is given by

$$U/U_{ss} = 1 - e^{-t/T} \tag{3}$$

where T is the "characteristic time" of the system, and is defined by

$$T = I/s_e \tag{4}$$

It should be noted that as long as there is a disturbing torque, there is an error, but the error can be made very small be increasing the sensitivity of the control.

NON-IDEAL CONTROL

Actual controls possess inertia, have some form of damping to prevent increasing oscillations, and therefore do not act instantaneously. In the present development it will be assumed that there is no lag between the motion of the output member of the control and the application of the controlling torque. This probably holds very closely for controls similar to the constant speed propeller where the change in blade angle is followed at once by a change in the load on the engine, and may be a poor approximation when there is appreciable "power lag" as exists between valve movement and engine power in a steam engine.

The equations of motion can then be written for the motion of the control and controlled systems. Den Hartog[3] has carried this procedure to the point of establishing stability relations. Let

x = displacement of a reference point on the control

m = equivalent mass of the control referred to x

c = viscous damping (dashpot) in the control referred to x

k = "static stability" of control = force in control opposing displacement of control per unit displacement (spring, etc.)

C_1 = controlling torque exerted per unit displacement of control

C_2 = force tending to move control per unit speed error.

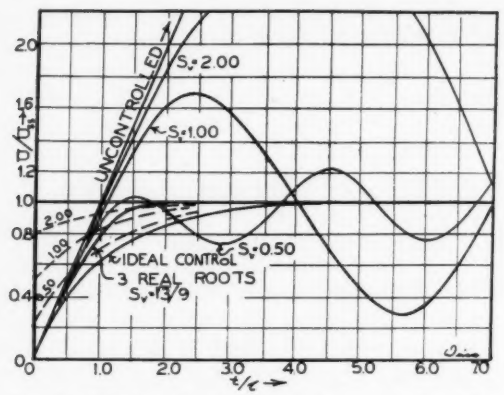

FIG. 1. Solution of critical cases of error produced by constant load.

It will then be noted that

$$s_v = C_1C_2/k \tag{5}$$

The equations for control and controlled member are

$$C_2U - m\ddot{x} - cx - kx = 0 \tag{6}$$

$$L - I\dot{U} - C_1x = 0 \tag{7}$$

The motion of the control is only of secondary interest, and so these equations will be solved for U. Substituting from Eq. (7) into Eq. (6),

$$\frac{d^3U}{dt^3} + \frac{c}{m}\frac{d^2U}{dt^2} + \frac{k}{m}\frac{dU}{dt} + \frac{s_vk}{Im}U = \frac{Lk}{Im} \tag{8}$$

Den Hartog has shown by means of Routh's discriminant for the cubic that this equation establishes stable motion if

$$(c/m)(k/m) > s_vk/Im$$

or

$$c > ms_v/I \tag{9}$$

The following conclusions are at once evident.

1. The control is unstable without damping (the instability taking the form of an increasing oscillation).

2. Stability of the system is decreased by large control inertia and sensitivity, and increased by large inertia of the controlled system and by damping in the control.

Dimensionless Form of Equation

Before proceeding with the solution of the cubic it is desirable to non-dimensionalize Eq. (8). From Eq. (6), if the control is considered as a simple one degree of freedom system in itself, and coupling C_1 is disconnected while the speed of the controlled member remains temporarily constant, then if the control is displaced slightly and allowed to return to equilibrium, its equation of motion is

$$\ddot{x} + (c/m)\dot{x} + (k/m)x = 0 \tag{10}$$

which can be written as

$$\ddot{x} + 2\zeta\omega_n\dot{x} + \omega_n^2x = 0 \tag{11}$$

where

$\omega_n = \sqrt{k/m}$ = natural undamped frequency of the control

ζ = damping ratio of the control, the ratio of the amount of damping present in the control to the amount necessary to produce critically damped motion (motion just short of being oscillatory).

Define a *control constant* S_v such that

$$S_v = s_v/I\omega_n$$

Then Eq. (8) becomes

$$\frac{d^3U}{dt^3} + 2\zeta\omega_n\frac{d^2U}{dt^2} + \omega_n^2\frac{dU}{dt} + S_v\omega_n^3U = \frac{L}{s_v}S_v\omega_n^3 \tag{12}$$

and the solution can be written in terms of the natural frequency of the control and the two dimensionless parameters ζ and S_v as

$$U/U_{ss} = \omega_n f(S_v, \zeta) \tag{13}$$

Solution for Particular Conditions

Eq. (12) can be solved simply when from Eq. (9)

$c = ms_v/I$ or in dimensionless form

$$S_v = 2\zeta \tag{14}$$

The system will then perform an endless oscillation after any disturbance, that is, it will "hunt." The solution is obtained under the condition of Eq. (14) by noting that two of the roots of the resulting cubic are pure imaginaries, and the third contains all of the damping of the systems. Solving Eq. (12) in the usual manner, and inserting initial conditions, the solution is given by

$$U/U_{ss} = 1 - \frac{1}{S_v^2 + 1}e^{-t/T} + \frac{S_v^2}{\sqrt{S_v^2 + 1}}\cos\left(\frac{1}{S_v}\frac{t}{T} - \phi\right) \tag{15}$$

where

$$\phi = \tan^{-1}(-S_v) \tag{16}$$

Evidently, the amplitude of the oscillation increases very rapidly with S_v.

A simple solution is also obtained when the cubic has three equal real roots. This occurs for $S_v = \sqrt{3}/9$, and $\zeta = \sqrt{3}/2$ The solution is then,

$$U/U_{ss} = 1 - e^{-3t/T} - 2(t/T)e^{-3t/T} - 3/2(t/T)^2e^{-3t/T} \tag{17}$$

Response curves for these expressions are plotted in Fig. 1. The dotted lines are the exponentials about which the oscillations take place. Note that the rate

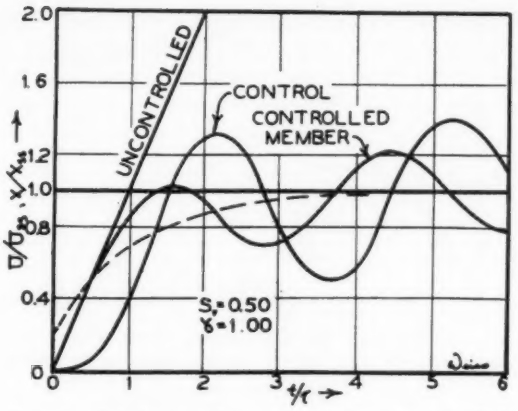

FIG. 2. Relative motion of control and controlled member.

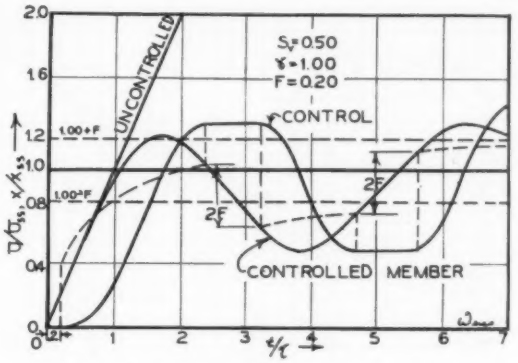

FIG. 3. Effect of Coulomb friction on speed error.

of increase of the error is smallest with the ideal control, and that a control with a large "control constant" is very undesirable.

Relative Motion of Control and Controlled Member

Solving Eqs. (6) and (7) for the motion of the control allows the relative motion of control and controlled member to be illustrated. This is best shown in Fig. 2 which has its constants so chosen as to represent unending oscillation. For simplicity the motion was allowed to represent unending oscillation. The lag of the control is clearly evident, and for this critical case the error is a maximum when the control is in a neutral position. If the control were allowed to overshoot a little more on each swing (by decreasing its damping) the error surges would become increasingly greater, and the motion would be unstable.

Effect of Coulomb Friction

Suppose now that there is dry or Coulomb friction in the control, that is, a constant retarding force independent of displacement or velocity. Let f = friction force.

Then adding f to the right-hand side of Eq. (6) it can be seen that the control will not begin to move until $C_2U = f$. Define, therefore a friction error range $U_f = f/C_2$.

U_f is then the ultimate, or residual error in the control, and the speed cannot be held constant in any position of the control to within $2U_f$. This residual error is decreased by reducing the Coulomb friction and by increasing the coupling ratio C_2.

The motion when Coulomb friction is present must be treated in parts, as the friction changes its sign whenever the control reverses its direction of motion. The solution has been carried through for a particular case and is plotted in Fig. 3. Compare Fig. 3 with Fig. 2, since both represent the same system except for the addition of friction. The dimensionless friction constant F is defined by

$$F = U_f/U_{ss} = (f/L)(s_e/C_2)$$

The cumulative effect of friction, then, is the same as if the axis about which the oscillation occurred expanded into a band $2U_f$ wide ($2F$ in dimensionless form), inside of which the error varied without restraint from the control. Thus it is apparent that Coulomb friction is definitely undesirable.

General Solution of the Motion

The general cubic, Eq. (12), cannot be solved simply, but its roots can be expressed as functions of S_r and ζ and therefore a chart can be drawn for each of the three roots in terms of the two parameters. Since the oscillatory case is of most interest, charts are presented in Figs. 4, 5, and 6 for the magnitude of the simple exponential, the real part of the complex root, and the frequency of the oscillation.

The form of the solution is

$$U/U_{ss} = 1 - A_1 e^{-r_1\omega_n t} - e^{-r_2\omega_n t}(A_2 \cos r_3\omega_n t + A_3 \sin r_3\omega_n t) \quad (18)$$

where

$$A_1 = \frac{r_2^2 + r_3^2 - 2r_2S_r}{(r_1 - r_2)^2 + r_3^2} \quad (19)$$

$$A_2 = \frac{r_1^2 - 2r_1r_2 + 2r_2S_r}{(r_1 - r_2)^2 + r_3^2} \quad (20)$$

$$A_3 = \frac{S_r(r_2^2 - r_1^2 - r_3^2) + r_1r_3^2 + r_1^2r_2 - r_1r_2^2}{r_3(r_1 - r_2)^2 + r_3^2} \quad (21)$$

Quantities r_1, r_2, and r_3 are obtained from the charts. r_3 is given as ω/ω_n, and is the ratio of the frequency of the actual oscillation to the natural undamped frequency of the control. It is easily shown that when the system is critically stable and performs unending oscillation, this ratio is unity. The oscillation therefore takes place at the natural frequency of the control.

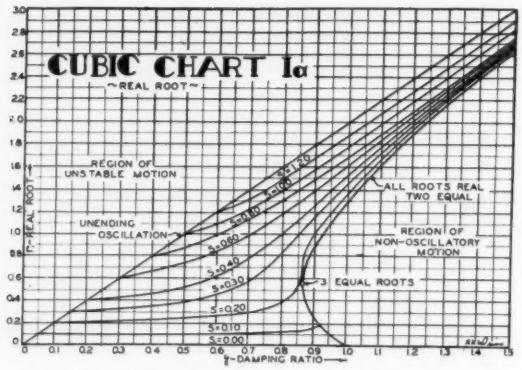

FIG. 4. Effect of parameters on real root of cubic.

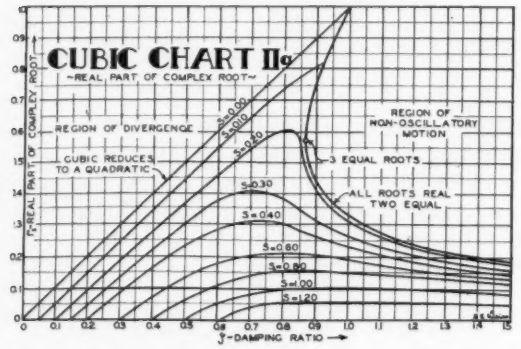

FIG. 5. Effect of parameters on real part of complex root of cubic.

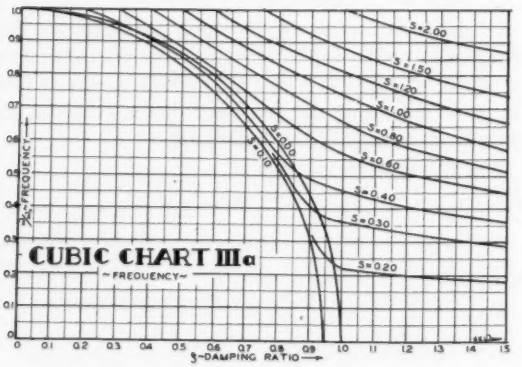

FIG. 6. Effect of parameters on frequency of cubic.

Fig. 5 shows the interesting fact that when the control constant of the system is held fixed, there is a value of damping ratio for which the oscillation has an optimum rate of decay. Fig. 4 shows that the simple exponential disappears satisfactorily for this value of damping and the probable range of system constants, and so this seems a convenient method of selecting the most desirable damping ratio in a control when the linkages, spring constants, etc., have been established. The variation of frequency ratio with S_v and ζ is shown in Fig. 6. Here it is evident that the frequency ratio varies rapidly with control constant over the range of

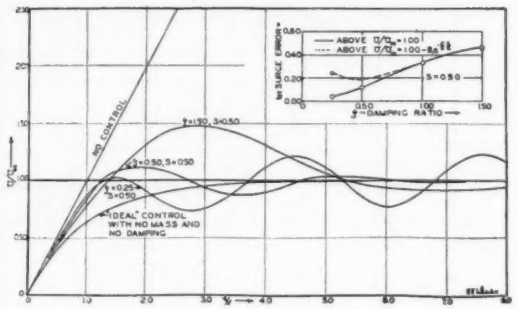

FIG. 7. Effect of damping on speed error.

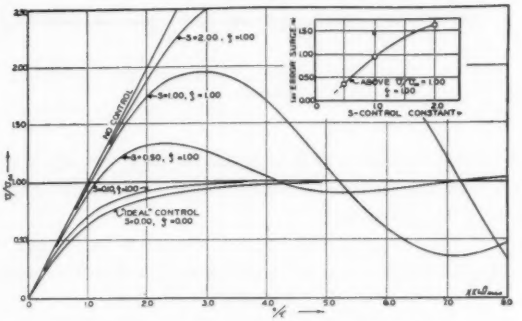

FIG. 8. Effect of control constant on speed error.

values presented, but that beyond critical damping, the effect of a change in damping ratio on the frequency ratio is small.

EFFECT OF VARYING PARAMETERS

The complete solution of Eq. (18) was obtained while S_v and ζ were varied systematically. Fig. 7 shows the effect of holding S_v constant and increasing the damping from the minimum required for stability to a comparatively large value. While the initial surge error increases steadily, as shown by the insert in Fig. 7, the increase is hardly catastrophic. The most advantageous response seems to be obtained when the damping ratio is selected according to Fig. 5. The broken line in the insert of Fig. 7 gives the initial surge error as measured above the exponential instead of the $U/U_{ss} = 1.00$ axis. It indicates that the reduction in surge error at low damping ratios is mostly obtained by a decrease in the magnitude of the exponential term.

Increasing the control constant while holding the damping ratio constant, as illustrated in Fig. 8, causes the error surges to increase very rapidly. A comparison of Fig. 7 and Fig. 8 suggests that when a control is unsatisfactory in the error surges which it allows, the fault lies in too large a control constant rather than too much damping.

EFFECT OF A SINUSOIDALLY APPLIED LOAD

When the disturbing load varies periodically, it is possible to obtain a resonant magnification of the

error. Since any repeated motion can be expressed as the sum of sine and cosine terms in a Fourier series, it is sufficient to investigate the response of the controlled system to a simple sinusoidal forcing function. Let this forcing function be

$$F(t) = Le^{i\omega_f t} \tag{22}$$

where

L = maximum amplitude of load surge
ω_f = forcing frequency.
Let $\beta = \omega_f/\omega_n$ = ratio of forcing frequency to natural frequency of the control
and U_{fa} = "static error" = steady state error produced by a constant load L.

Generally, only the amplitude of the steady state motion will be of interest, in determining whether dangerous amplification of the error surges will occur when the system is subjected to a particular frequency. The magnification of the error can be obtained in a manner similar to that applied to a one degree of freedom system,[4] and defining magnification as μ where

μ = maximum amplitude of surge error divided by the static error

the magnification is given by

$$\mu = S_v/\sqrt{(S_v - 2\zeta\beta^2)^2 + (\beta - \beta^3)^2} \tag{23}$$

This expression is a maximum when the damping is fixed by

$$S_v = 2\zeta\beta^2 \tag{24}$$

in which case the magnification is

$$\mu_{max} = S_v/(\beta - \beta^3) \tag{25}$$

The possible error at any frequency ratio, therefore, varies directly with S_v. There is a lower limitation on damping, however, imposed by the requirement that the system be stable, that is, exhibit no increasing oscillations, which is given by Eq. (9). Inserting the critical condition from Eq. (14) into Eq. (23), it will be found that for β greater than about 1.56, the maximum possible magnification will be less than 1.00, and therefore, there is no danger of resonance beyond this point, if the control is stable.

Fig. 9 shows the effect of damping ratio and control constant on the magnification. It is at once evident that reducing the control constant is much more beneficial than increasing the damping, and as when the response to a sudden load was considered, the best control is one with a small control constant, and moderate damping.

Addition of Derivative Component

An improvement on the simple error control which naturally suggests itself, is the addition of a derivative component so that the controlling force is proportional

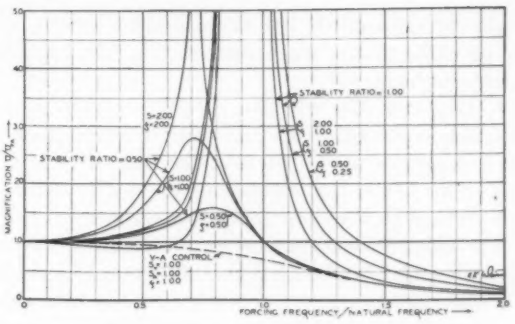

FIG. 9. Error magnitude produced by sinusoidally applied load.

to the rate at which the error is changing as well as to the magnitude of the error. Define

s_a = sensitivity of acceleration component = controlling torque applied per unit rate of change of error
S_a = acceleration control constant = s_a/I.

For the ideal control, rewriting Eq. (1) to include the new component gives

$$L - I\ddot{U} - s_a\dot{U} - s_cU = 0 \tag{26}$$

And the new component affects the inertia directly, increasing or decreasing the effective inertia of the controlled member according to the sign of s_a. As it has been previously shown that a large value of I is desirable, the effect of the derivative component is beneficial.

When the control has inertia itself, and damping, the relations are not so simple. However, the procedure of analysis is exactly analogous to that followed for the simple error control and an equation in U is

$$\frac{d^3U}{dt^3} + 2\zeta\omega_n\frac{d^2U}{dt^2} + \omega_n^2(1 + S_a)\frac{dU}{dt} + S_v\omega_n^3U = \frac{L}{s_v}S_v\omega_n^3 \tag{27}$$

Compare this with Eq. (12). The new system can be expressed in terms of an equivalent simple system if the following substitutions are made.

$$I_1 = I(1 + S_a) \tag{28}$$

$$\omega_{n1} = \omega_n(1 + S_a)^{1/2} \tag{29}$$

$$S_{v1} = S_v/(1 + S_a)^{3/2} \tag{30}$$

$$\zeta_1 = \zeta/(1 + S_a)^{1/2} \tag{31}$$

In other words, there are no new ideas introduced by the derivative component, but the parameters expressing the performance of the original system are changed by the introduction of the new law of control. With S_a positive, as is evidently desired, the equivalent inertia of the controlled member is increased. This could not be accomplished by a simple control, but

could be represented by an equivalent system with simple error control when the inertia of the controlled member is increased.

Noting that the effective control constant is considerably reduced, and that the effective damping ratio decreases somewhat less, the derivative control is seen to follow the conclusions previously drawn in establishing good characteristics of a control.

The effect on the response of the controlled system to a repeated disturbance is also determined by making the same substitutions. A single case has been calculated and plotted in Fig. 9, as a dashed line marked "V-A control." The improved response is explained by noting that the equivalent control constant has been reduced from 1.00 to 0.355, while the equivalent damping ratio has been reduced only from 1.00 to 0.707.

General Conclusions

It is now possible to draw some general conclusions for constant speed controls. The basic condition for the type of control discussed is that the steady state or static error should be small. This means a high control sensitivity s_v. Since control constant S_v equals $s_v/I\omega_n$, high sensitivity tends to make the control constant large. But S_v should be small to improve the dynamic characteristics of the control. The inertia of the controlled system is usually fixed, so that the natural frequency of the control must be as high as possible to counteract the undesirable effects of high sensitivity. Natural frequency is made large by decreasing the inertia of the control, and by increasing its static stability k. But by Eq. (5) increasing k decreases sensitivity, so to retain s_v large, the two coupling ratios must be large.

The only non-contradictory condition, therefore, is that the control inertia should be as small as possible. Coupling ratios should be large, which agrees with the desirability of keeping the effect of Coulomb friction small, and the amount of damping should be moderately in excess of the minimum required for stability, and can be chosen by the peaks in Fig. 5.

The addition of a derivative control is beneficial, especially when design limitations prevent the inertia of the control from being reduced as much as might be desired.

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Stresses in a Partially Inflated Free Balloon—with Notes on Optimum Design and Performance for Stratosphere Exploration

RALPH H. UPSON

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IN ANY balloon the partially inflated condition is the most widely applicable. This is particularly emphasized in the stratosphere balloon by its very small proportion of initial inflation, which in the case of the National Geographic Society–Army Air Corps "Explorer" was only about 7 percent of the gross volume; and by the fact that motions and stresses are both more critical at the lower altitudes where the degree of inflation is a minimum. Numerical solutions for typical conditions show that forces other than lift and weight can usually be neglected when considering stresses in the fabric or alternative skin, which is here assumed to carry the entire load.

The following specific assumptions apply in the initial analysis:

(1) Flexible weightless skin, inextensible in tension.

(2) Load distributed uniformly around the circumference of any horizontal section below the gas level, thus including most of the actual skin weight.

(3) Actual gas volume small in proportion to designated spherical volume of balloon.

(4) Pressure considered due to gas head alone (no aerodynamic or inertia forces).

(5) Absolute temperature of gas remains approximately equal to or proportional to that of outside air, a small difference here being of no consequence except for direct control.

(6) Negligible change in gas density due to compression relative to outside air (not strictly applicable to the case of a rubber balloon at extreme altitudes).

Let

p = pressure (lbs. per sq.ft.) at any point x, y (x being the horizontal distance out from the vertical axis and y the vertical distance above the lower free surface of gas)

x_1, y_1 = coordinates of surface profile at edge of spherical cap (Fig. 1)

x_0 = x where $y = 0$; $y_0 = y$ where $x = 0$

vol. = actual gas volume (cu.ft.) at any altitude

vol._0 = total design volume (cu.ft.)

vol._1 = gas volume at start

δ = gas lift (lbs. per cu.ft.)

δ_{SL} = same referred to sea level

T = meridian tensile stress across a horizontal section through the deformed fabric surface (lbs. per ft. of designed periphery)

R = radius of deformed meridian element at any point (ft.)

R_0 = designed radius of great circle

r = horizontal designed radius at any point y on the vertical axis

β = angle of tangent to meridian curve

σ = the air density (relative to sea level)

σ_0 = value of σ at which gas fills balloon

σ_1 = value of σ at starting altitude

n = ultimate load factor

W = weight, exclusive of gas

K_v, K_T, K_s, K_g are coefficients of volume, tension, structural weight, and gas proofing weight, respectively.

Method

According to the assumed conditions, there must be a meridian component of tension at all points; but in any region where the fabric is slack around the circumference of a horizontal section, the stress perpendicular to a meridian is zero. In any such region the total meridian tension carried by the fabric must remain the same over the entire circumference of *any* horizontal section. Thus, referring to Fig. 1, the total load carried,

$$2\pi rT = 2\pi r_0 T_0 = \delta \text{ vol.}/\sin\beta_0$$

from which $T = \delta \text{ vol.}/2\pi r$ for $\sin\beta_0 \approx 1$ (1)

the latter being always substantially true for the nearly vertical foot-ropes at the start of a high ascent.

Following the stress up a meridian above the designed equator of the balloon, there is obviously an increasing concentration, with reduction in r, until the profile of the deformed section merges with the design profile of the balloon. The latter is the only condition that prevents the stress becoming infinite at the top of the balloon. Further analysis thus depends on determining the shape of the deformed balloon for comparison with the designed shape. The extreme case where the horizontal tension is zero throughout the entire surface, as would be the case with a finite volume of gas in an infinitely large balloon, will be treated first. The balance of forces on any small element of the curve makes $p = \delta y = Tr/Rx$ which, from Eq. (1), by transposing, becomes

$$1/R = 2\pi xy/\text{vol.} \tag{2}$$

or

$$-d^2y/dx^2 \frac{1}{[1 + (dy/dx)^2]^{3/2}} = \frac{2xy}{\int_0^{y_0} x^2 dy} \tag{3}$$

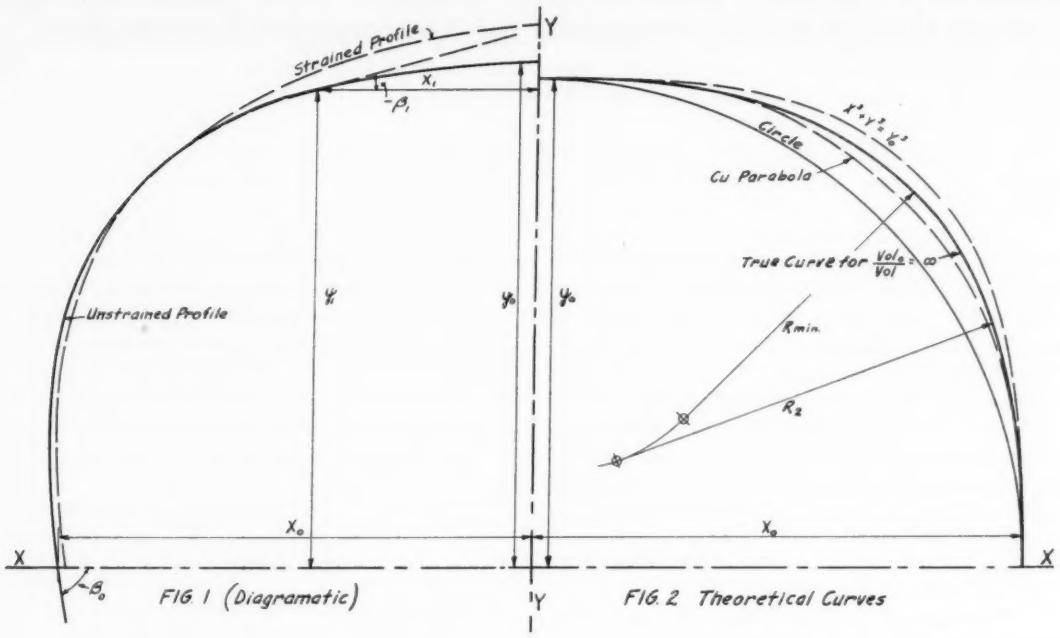


FIG. 1 (Diagramatic)

FIG. 2 Theoretical Curves

This is the basic equation of the profile shape, the surface being generated by the revolution of the first quadrant portion around the Y axis. Its practical solution now depends on certain simplifying assumptions.

First assume $\beta_0 = \pi/2$, which puts the X axis where x has its maximum value $= x_0$ (Fig. 2). For this condition, it is clear from inspection of Eq. (2) that a curve symmetrical about a 45° axis results. This makes $y_0 = x_0$ and the volume can then be expressed by the relation,

$$\text{vol.} = K_v y_0^3 \tag{4}$$

where K_v is a coefficient to be determined.

Further examination of the curve represented by Eq. (3) proves that it lies between the two approximate forms shown by the dashed lines in Fig. 2, the inner one having $K_v = 2.35$ and the outer one 2.53.

Hence, in view of the small range of possible error, an intermediate value of $K_v = 2.44$, is chosen. This value is approximate in the second decimal place.

Stress Distribution

Substituting Eq. (4) in Eq. (1), the stress at any point x, y on the middle curve of Fig. 2 is:

$$T = K_v \delta y_0^3 / 2\pi r \tag{5}$$

But at the extreme top $r = x = 0$, and by Eq. (2), the curvature would be zero, which is not actually the case in a balloon of finite size. Out to a value of $x = x_1$, in the practical case, the fabric is constrained to follow the designed radius R_0 by the circumferential elements of fabric running horizontally around the balloon.

In the absence of shear, at any point where there is not actual slack, the balance of forces gives the general equation of stress,

$$p = \delta y = (T_m/R_m) + (T_c/R_c) \tag{6}$$

where T_m and T_c, R_m and R_c are the tensions and radii in the two principal directions, respectively.

At the edge of the taut cap, the second term in Eq. (6) vanishes and

$$\delta y_1 = T_1/R_1 \text{ or } T_1 = \delta y_1 R_1 \tag{7}$$

But by symmetry, at the apex of the balloon

$$\delta y_0 = 2T_0/R_0 \text{ or } T_0 = {}^1/_2 \delta y_0 R_0 \tag{8}$$

On the assumption of completely flexible fabric, there can be no sharp break in the profile curve; hence there can be but one value of β_1 at the edge of the spherical cap. Also, if the cap adds a negligible volume to that contained within the theoretical profile of Fig. 2, the vertical balance of forces requires the profile curve in the slack portion to remain the same as if it were all slack. Thus, R_1 in Eq. (7) is the value of R in Eq. (2) at the point where $dy/dx = \tan \beta_1$ of the spherical cap.

By integrating the top portion of Eq. (3), using the relations, $\dfrac{d^2y}{dx^2} \approx \dfrac{1}{R}, \left(\dfrac{dy}{dx}\right)_1 = \tan \beta_1 \approx \beta_1 \approx \dfrac{x_1}{R_0}; \; y_1 \approx y_0,$ one obtains

$$x_1 = K_v y_0^2 / \pi R_0 \text{ and } R_1 = R_0/2 \tag{9}$$

But to satisfy the vertical balance of forces, the meridian tension T_m just above the point x_1, y_1 must equal the tension just below. Then, as T_c in Eq. (6) is zero below this point, T_c just above must equal $T_m \approx T_1 \approx T_{max.}$. And at the same point, from Eq. (9), $R_m = R_c = R_0 = 2R_1$. Except for the slight increment of gas head in the cap itself, this makes the

tension uniform in all directions and at all points in the spherical cap.

Evaluation of Tensions

Taking the maximum tension from Eq. (8) and substituting $R_0 = [(3/4\pi)\ \text{vol.}_0]^{1/3}$ and $y_0 = (\text{vol.}/K_r)^{1/3}$, the following simple expression (for any altitude) results.

$$T_{max.} = K_T\delta\ \text{vol.}^{1/3}\cdot\text{vol.}_0^{1/3} = K_T\delta_{SL}\ \text{vol.}_0^{2/3}\sigma^{2/3}\sigma_0^{1/3} \quad (10)$$

where
$$K_T = (3/4\pi K_r)^{1/3}/2 \quad (11)$$

The edge of the spherical cap, below which the tension falls off rapidly, is located, from Eq. (9), by

$$\frac{x_1}{R_0} \approx \frac{K_r y_0^2}{\pi R_0^2} = \frac{.257}{K_T}\left(\frac{\text{vol.}}{\text{vol.}_0}\right)^{2/3} \quad (12)$$

For the special case, already considered, of $R_0 = \infty$ and $\beta_0 = \pi/2$, $K_r = 2.44$ and, from Eq. (11), $K_T = .23$. This assumes $\text{vol.}/\text{vol.}_0 = 0$; but for the proper value of K_T Eq. (10) is good for any other specific volume ratio.

A graphical approximation using practical values of initial $\text{vol.}/\text{vol.}_0$ and B_0 shows that K_T has a value only slightly higher than for the above ideal case. Although the effect of the fabric weight is to lower slightly the value of K_T, the latter effect must be small, since the weight per sq.ft. is less than 2 percent of the gas-head pressure. Thus in practice it is permissible to put $K_T = .25$ to $.29$ in Eq. (10) and Eq. (12), the larger value for $\text{vol.}/\text{vol.}_0 \approx 1/5$. For a still larger volume ratio, approaching unity, K_T increases to about .39; although the net effect of altitude in a given flight is substantially to decrease the stress from that at the start.

The above includes most of the practical static factors, except the extension and deformation of the fabric threads under load. The latter is a problem whose solution depends on experimental data, but in general the theoretical tensions will be on the safe side.

Some Effects on Design and Performance

The tension in a balloon not only governs the stress analysis of a specific unit, but also largely dictates the proper size, and the ultimate altitude.

Considering only the balloon proper, its principal weight can be assumed divided into two parts: (1) structural weight W_s comprising the bare fabric; and (2) gas proofing W_g of rubber or equivalent.

If W_1 is the net load to be carried, the total weight (exclusive of gas) is:

$$W = W_1 + W_s + W_g = \delta_1\ \text{vol.}_0(\sigma_0/\sigma_1) \quad (13)$$

The structural weight can be expressed by a coefficient K_s, using the maximum tension from Eq. (10), such as to make

$$W_s = K_s n T_{max.}\ \text{vol.}_0^{2/3} = K_s K_T n_1 W\ \text{vol.}_0^{1/3}(\sigma_1/\sigma_0)^{2/3} \quad (14)$$

where the subscript 1 indicates starting conditions, for which the stress is maximum.

From the assumed constant weight of gas film per unit area,

$$W_g = K_g\text{vol.}_0^{2/3} = \frac{K_g W}{\delta_1\text{vol.}_0^{1/3}}\left(\frac{\sigma_1}{\sigma_0}\right) \quad (15)$$

It should be noted that $K_s n T_{max.}$ and K_g are each $(36\pi)^{1/3}$ times the corresponding weights per unit area of actual surface.

Considering now an extreme case where W_1/W is very small, one can assume $W_1 = 0$ and $\sigma_0 = \sigma_{min.}$ Substituting in Eq. (13) and rearranging,

$$n_1 K_s K_T\ \text{vol.}_0^{2/3}\left(\frac{\sigma_0}{\sigma_1}\right)^{1/3} - \text{vol.}_0^{1/3}\left(\frac{\sigma_0}{\sigma_1}\right) + \frac{K_g}{\delta_1} = 0 \quad (16)$$

Solving for the value of vol._0 that makes σ_0/σ_1 a minimum, and substituting:

$$\sigma_{min.} = \sigma_0 = (4n_1 K_s K_T K_g)^{2/3}\ \sigma_1^{2/3}/\delta_{SL}^{2/3} \quad (17)$$

to attain which one must make the gross $\text{vol.}_0 = (\sigma_0/\sigma_1)^2/8n_1^3 K_s^3 K_T^3$ (18)

For the "Explorer," starting from a 4000 ft. elevation, with $\text{vol.}_0 = 3{,}000{,}000$ ft.^{3}, and $\text{vol.}_1 = 210{,}000$ ft.^{3}, $\sigma_1 = .888$; $n_1 = 5.3$; $K_T = .26$; $K_s = .00014$; $K_g = .10$; $\delta_{SL} = .07$.

For an unmanned or otherwise safeguarded balloon, n could undoubtedly be cut to about 4; a lower value would make ground handling hazardous. Applying the above optimum equations to a larger balloon of similar design, one gets a possible $\sigma_{min.} = .0136$ for a gross $\text{vol.}_0 = 9{,}500{,}000$ cu.ft.

Assuming the desirability of exploring still higher altitudes, a further increase in size is apparently of no avail, although the above optimum size is larger than anything built to date. A lower load factor, however, and better coordination of material would be a marked help. The importance of the load factor is better appreciated from the fact that the above hypothetical balloon at maximum altitude would show a value, from Eq. (10), of

$$n_0 = n_1(\sigma_1/\sigma_0)^{2/3}K_T/K_{T_0} = 43.5 \quad (19)$$

and the gain in volume from higher stressing would be slight. In other words the balloon must carry a ten times excessive load factor at altitude, just to be able to get off the ground safely.

This handicap can be largely obviated by the relatively simple expedient of doing away with the woven fabric and building the balloon of sheet rubber, graduating the thickness to put the strength where it is needed, or reinforcing by rubber seams and strips. As Jean Piccard has pointed out, in the case of any rubber balloon, the load factor decreases with altitude, and can thus be made any desired magnitude. The optimum size will still be large, though not prohibitive,

for what is believed to be a practical minimum thickness.

For carrying solely instruments and broadcasting equipment, with a parachute, the balloon can, of course, be allowed to burst at maximum altitude, thus making $n_0 = 1$. For man-carrying purposes, one or more of the following procedures seem possible: (a) hang the entire gondola on a parachute, and let the balloon burst; (b) stop the ascent while the rubber still has a proper margin of expansion, if this can be satisfactorily determined; or (c) use Piccard's cluster of smaller balloons. In the latter case, performance will be improved by using the fewest balloons that will insure adequate safety. The gain in respect to material is so great however that rubber balloons much smaller than fabric ones will give superior results, providing various conditions affecting their construction and use can be satisfactorily met. These include: (1) Availability of a reliable cement for seams and reinforcements (see also item 4). (2) Close inspection of entire surface, to avoid any flaw that might cause premature bursting. (3) Avoidance of puncture during ground handling; important, not so much for its likelihood of occurrence, as for the great reduction of maximum altitude that a small puncture would entail. (4) Reasonable resistance to the effects of intense ultraviolet radiation by day or a temperature approximating $-55°$C. by night. (Although the air temperature is the same by day, the balloon will be warmed by the sun to a temperature probably well above freezing.)

Tentative, but conservative, computations show that with a large rubber balloon, a man could ascend to where the air density is one two-hundredth of its sea level value, while an unmanned balloon of modest size could be sent up to where the relative density is less than one one-thousandth, or an altitude of some thirty miles

Book Review

Jane's All the World's Aircraft, 1938, edited by CHARLES GREY and LEONARD BRIDGMAN; Sampson Low, Marston and Company, Ltd., London, 1938; 596 pages, 2 pounds, 2s.

When one finds one's self in complete agreement with Charles Grey one wonders. Usually in the preface to this standard reference work he expresses opinions that provoke discussion. This year his comment is so factual that it is difficult to disagree with him, a state of affairs which will probably disappoint him.

As the introduction was written shortly after the Munich Conference, Mr. Grey, like many others, felt that this agreement assured a prolonged peace. A little later, opinion in England seemed to change as is indicated by the feverish activity in their aircraft factories. The effect of this tension in world aircraft affairs, which naturally makes secrecy more imperative, has not had any appreciable ill effect on the information obtainable regarding the latest aircraft which are in production in the various countries. When 316 pages can be covered with pictures and descriptions of airplanes the book continues to be the outstanding reference work in the aviation field.

The French section is somewhat restricted owing to the slowing up of aircraft development during the period of nationalization of the French aircraft industry. Mr. Grey correctly appraises this situation when he writes:

"That is a tragedy for the World's Aviation, because right from the beginning of aviation French ingenuity and French quickness of wit have produced numbers of new types which, if not all successful, have at any rate stimulated competing nations, especially ourselves, to improve upon the designs of such machines and to beat their performances. But, when one has made all allowances, the fact is made clear that an industry which has been nationalised on the French system has its style and its initiative hopelessly cramped."

The Russian section is hidden behind a veil of secrecy but it is surprising that so much information appears. Mention is made of the unknown fate of the greatest of Russian airplane designers, A. Toupoleff, who was arrested as an "enemy of the people" together with some of his collaborating engineers. It is possibly true, as Mr. Grey believes, that the U.S.S.R. airplane and engine factories are mainly devoted to adapting the best foreign technique to Russian requirements. Whatever may be the exact condition, it is generally believed that the production possibilities of Russian aircraft factories are large and the size of the Soviet air fleet equals that of any other nation. No country in the world has such a large aviation Society as the "Osoaviakhim" with its seven million membership. With fifteen aircraft factories and four aero engine plants located at strategic points, Russia is apparently well equipped for production.

The sections devoted to the United States are excellent, as usual. Apparently our aircraft companies realize the importance of being well represented in a book that is referred to in every country of the world.

Equally valuable are the sections on Civil and Military Aviation. Here may be found useful compilations of information regarding air transport, flying clubs, aero publications, airports, and the service organizations of each country.

Collaborating with Mr. Grey are three associates, Mrs. C. M. McAlery, one of the ablest writers on British aviation; Leonard Bridgman, who deserves credit for the laborious work of obtaining and editing the information in the book; and Mr. Thurstan James, who is one of the editors of *The Aeroplane*.

The pictorial quality of this year's volume is excellent, particularly in the presentation of new airport buildings. No one who is proud of the great system of airways in the United States can see the great facilities for passengers in other countries without wishing that we in this country were more advanced in this respect.

Again, as for many years, Mr. Grey and his associates merit the gratitude of aviation people for their invaluable contribution to world aeronautical information.

LESTER D. GARDNER

Book Review

The Internal Combustion Engine, by C. FAYETTE TAYLOR and EDWARD S. TAYLOR; International Textbook Company, 1938; 317 pages, $3.50.

In explaining the purpose of this book, the authors state that "the object of this volume is to furnish a basic understanding of the functioning of the internal combustion engine which may serve as a foundation for design or research in this field. Familiarity on the part of the reader with the principles of elementary physics, mechanics, and thermodynamics is presupposed." The chapters of the book might have been grouped into six divisions: (1) Operating Cycles, (2) Combustion, including detonation in both the spark-ignition and compression-ignition engine, (3) Heat Losses, (4) Friction, including lubrication, (5) Breathing Capacity of four- and two-stroke engines, and (6) Engine Performance.

The explanation of the thermodynamics of the fuel-air medium and of the fuel-air cycle within the cylinder is the most complete that has come to the attention of this reviewer. Of particular interest is the discussion of the temperature variation within the combustion chamber. The fact that the temperature within the gases is not uniform has not heretofore been given sufficient emphasis. The solution of numerical examples helps to make this section (which is always the most difficult to follow in a discussion of internal combustion engines) more understandable. The numerous figures in this section of the book should be studied diligently because they explain much of the observed engine data. Considerable material is presented on the effects of the various engine-operating variables on the flame speed. The reviewer is of the opinion that the explanation of the observed data would have been simplified had density rather than pressure been used as one of the independent variables. The authors state that the increase of flame speed with increasing engine speed "is undoubtedly due to the marked effect of turbulence." Although this explanation is the one most generally accepted, it has never been definitely proved nor has it been possible to observe experimentally the mechanism by which turbulence increases flame speed. It would seem safer to state that this is the most logical explanation rather than a certainty. Incidentally, as partial proof of the statement, Schnauffer's work is referred to as showing the effects of turbulence on flame speed when engine speed was maintained constant. Actually, in Schnauffer's tests the turbulence was varied by varying the engine speed as has been the case with most tests on the effects of turbulence.

In the discussion on detonation, emphasis is placed on the compression-ignition theory. The various other theories that have been advanced from time to time are not discussed and this omission is probably just as well. Although the compression-ignition theory has more data to support it than do any of the other theories, even with it there are some weak links in the chain of evidence. One stumbling block in this case is the fact that, whereas benzene and toluene do not detonate (the reviewer prefers the term "knock"), they do preignite. This chapter could well have included some of Draper's very excellent work on the pressure waves existing in the cylinder following detonation.

The reviewer has only one criticism of the chapter on combustion in the compression-ignition engine. The statement is made that "it seems impossible to reduce the time for combustion inversely as the engine speed, which fact, together with the tendency of the delay period to remain constant, imposes a limit on the maximum r.p.m. at which a compression-ignition engine of a given design will operate satisfactorily." It is difficult to find any reference based on experimental data to show that there is any practical speed limit, from the standpoint of combustion rate, above which the compression-ignition engine cannot be operated.

The chapter on mixture requirements of the spark-ignition engine and that on fuels for internal combustion engines contain a better discussion of these subjects than the reviewer has seen elsewhere. The explanation of the effect of fuel vaporization on operating and on starting characteristics is particularly good.

The heat losses are considered from their relationship to engine power and not from the standpoint of designing adequate methods of engine cooling. The first part of this chapter consists of an application of dimensional analysis to the problem of heat flow through the engine following the method used by Pinkel. The second part of the chapter contains the results of experimental tests showing the variation of heat losses with the different engine variables. Particularly interesting is the statement that "if it is assumed . . . that the indicated thermal efficiency is 30 percent suppression of the heat losses would increase this to 31.5 percent only." The authors then discuss the reasons for controlling heat flow.

The chapter on engine friction divides this subject into pumping losses and mechanical friction, the former being treated in some detail. The chapter is concluded with a discussion of the methods of measuring friction. The study of friction is followed by the chapter on lubrication. As was the case with heat losses, the general theory is covered. The relationship of viscosity to friction is emphasized. It is gratifying to see the viscosity given in most cases in centipoises rather than in Sabolt seconds. A conversion from the one unit to the other is given.

The air capacity of the four-stroke engine is covered in considerable detail. The theoretical discussion is supported with numerous experimental data. The authors have recommended that the correction of power for variation in inlet temperature be based on a function of the first power of the temperatures involved rather than the square root of the temperatures as has been done so frequently in previous work. This change is commended because the apparent variation of engine power with the inverse of the square root of the absolute inlet temperature is more fortunate than it is scientific. The chapter on the air capacity of the two-stroke engine follows the same general procedure as that for the four-stroke engine.

The concluding chapter on "Engine Performance" discusses the relationship between power, speed, and fuel consumption. The dimensional analysis that was used in discussing the breathing capacity of the engine is extended here to give a "figure of merit" for engines. The use of dimensional analysis by the authors is particularly beneficial. This method of attack has been too long neglected in applied mechanical engineering. The designation of mass rather than force as one of the three fundamental units would have been more conventional. The various methods of controlling both the spark-ignition engine and the compression-ignition engine are discussed for the unsupercharged and the supercharged engine. The book is concluded with an extensive bibliography, which will prove of great assistance to the reader who wants to study in more detail any particular phase of the subject.

The book is well illustrated with figures representing both experimental and theoretical results. The coordination between experimental and theoretical investigations is quite complete. The book is highly recommended for advanced students in internal combustion engineering and to those engaged in the development of or research on such engines.

A. M. ROTHROCK
National Advisory Committee for Aeronautics

Honors Night Meeting
New York, January 27, 1939

On the dais from left to right: Lloyd Espenschied, Commander F. W. Reichelderfer, Air Commodore E. W. Stedman, Dr. Lyman J. Briggs, Russell C. Newhouse, Major General H. H. Arnold, T. P. Wright, Dr. George W. Lewis, Edward J. Noble, Prof. A. V. de Forest, Group Captain George C. Pirie, Colonel Frank P. Lahm, Dr. J. C. Hunsaker, Corrington Gill.

Honors Night Dinner of the Institute of the Aeronautical Sciences

"HONORS NIGHT," the annual dinner of the Institute at which awards, Honorary Fellowships, Honorary Membership, and Fellowships are presented, was held at the Hotel Biltmore in New York on the evening of January 27, 1939. Over five hundred members and guests were present.

T. P. Wright, the retiring President of the Institute, gave the opening address.

There follows a condensed account of the meeting as the program was long and only excerpts from the speeches can be printed in the Journal. Formal salutations and acceptances are omitted.

Address by the Retiring President

This program comes at the conclusion of the Seventh Annual Meeting of the Institute. During this Annual Meeting there have been three days of technical sessions at which important papers of a scientific and engineering nature have been presented. Some papers have dealt with the airplane proper including its structure, its aerodynamic qualities, its powerplant, its propellers, its instruments, and the fuel and oil questions concerned with the powerplant. In addition, we have had papers on other types of aircraft than the airplane, such as lighter-than-air aircraft and rotating wing aircraft. Other papers have dealt with the uses to which airplanes are placed, notably air transport, during which problems of meteorology, radio, and physiology have been discussed. Finally, we have also discussed problems of education, so important in connection with the training of young men who will carry on in the future.

The increasing importance of the airplane in modern life is evident to everyone. Civil aviation in this country still leads the world by a considerable margin. There has been a great improvement in speed and safety of air transportation during 1938. On the basis of C.A.A. statistics, safety of air travel increased eighty-eight percent for 1938 over 1937.

One big question before our minds today is perhaps, how do we stand in military aviation? During the past few years several of us have had the opportunity of traveling in Europe and of there viewing the progress in air expansion. In 1934, upon returning from a rather extensive European visit, I found relatively little to report in the way of scientific and engineering improvements novel to the air industry in our country. The beginnings of big air expansion were in evidence but not too much had by then been accomplished. In 1936 a similar visit, including activities in England, France, Holland, and Germany showed a greatly changed condition. A vast expansion, particularly in Germany, had taken place, and was obviously proceeding on an accelerating basis. Tremendous research laboratories were viewed and in addition, a number of factories were visited where the rate of production was so far greater than had been seen previously anywhere in the world that it required seeing in order to believe it was possible. Few, I fear, therefore could believe the stories of this air expansion which we, who had seen it, reported upon returning.

Now again, in 1938, numerous visits were made by Americans to view the European picture and the estimates resulting check well with those prognosticated in 1936. Surely these estimates, made by such men as Al Williams, Tommy Tomlinson, Colonel Lindbergh, and S. Paul Johnston, could not be so incorrect that they did not in the aggregate, quite accurately represent the true state of affairs. Further substantiation would appear to be given to such estimates by the over-shadowing political influence which supremacy in the air gave to those countries who possessed such supremacy in 1938.

Paul Johnston and I, in London and again in Paris, compared notes on our observations during a recent trip to Europe and arrived at relative air strength for various countries, considering such factors as available first-line planes, personnel, quality of planes, present rate of production, capacity for expansion, and morale. This comparison is the following which assumes Germany on a basis of 10: Russia 7; Italy 6; England 4; France 2; United States 3.

It therefore becomes apparent that some degree of expansion in the air for the U.S. is essential. Fortunately, because of our still relatively isolated position, we have an opportunity to plan our expansion intelligently. We want a nucleus air force larger than our present one and certainly sufficient to meet demands of training and of establishing an industry which can further expand in case of emergency. Too large an immediate production increase may well bring about a situation whereby deliveries of the last lots of a given order will be obsolete when delivered. The size of the recently proposed increase appears correct. It is the proper planning of a logical expansion toward which we must strive. In this regard, I would call your attention to the very great efficiency which I feel has been achieved in Germany and which we should fully study and recognize when planning for ourselves. We can, I am sure, learn much from studying the planning she has used in expanding her air force. The burning question is: Can a Democracy act efficiently and still retain the fundamental Bill of Rights which we all feel is so essential? I, for one, believe that with proper planning this can be done.

In the final analysis scientific effort should perhaps better be expended in developing and improving government, economic, and social activity; but at present, however, security is in the minds of all and national defense can well receive the best work of our scientists and engineers. One fundamental of planning is constantly to bear in mind the necessity of maintaining proper sequence of research, development, and production, three distinct states in any proposed air expansion program. If we permit any of these stages to encroach too much on one another, confusion will very likely result.

Since the basis of any program of expansion must be research, it is important that sufficient funds be made available to permit us to regain and then retain the lead which, until very recently, we have had in this field. Our National Advisory Committee for Aeronautics has long been looked upon by other countries as the most important source of new aeronautical information. This progress has been consistent and steady; however, the development of research facilities has expanded so rapidly in Europe that we can now well look to our laurels. It is pleasing to note an apparent appreciation of these facts in Washington so that we can look forward with confidence to the availability of funds for research expansion in the N.A.C.A. and universities and, as well, expansion of development facilities and development orders for the industry.

In view of the great importance of research as the fundamental feature requiring immediate attention, it seems to me particularly appropriate that the next President of the Institute of the Aeronautical Sciences is to be a research man. Educated at Cornell University in engineering and after instructing in experimental engineering at Swarthmore and elsewhere, he joined the National Advisory Committee for Aeronautics in 1924 as Executive Director. In this capacity he has had the task of directing the research activities of the N.A.C.A. The high standing of the Committee's laboratories at Langley Field, appreciated not only in this country but throughout the world as well, attests to the success which he has attained and which indeed was recognized in 1936 by the award to him of the Daniel Guggenheim Medal. He has also been selected to present later this year the Wilbur Wright Memorial Lecture before the Royal Aeronautical Society in London.

Acceptance by Dr. George W. Lewis

In accepting the office of President of the Institute of the Aeronautical Sciences for the coming year, I am not only deeply appreciative of the honor you have conferred upon me, but I am grateful for the opportunity you have given me for useful and constructive work in this critical period in the history of aeronautical development.

During the past seven years, the Institute of the Aeronautical Sciences has prospered through the making and holding of new friends and in the rendering of essential services for the advancement of American aeronautics. Although young in years, the Institute has won recognition the world over as one of the most effective of scientific societies. This is a tribute to the soundness of its organization and to the competency of its management. So, naturally, I am happy tonight to have my name associated with those of my distinguished predecessors under whose leadership the work of the Institute has thus far been so ably advanced. In your name let me convey to our able retiring President, Ted Wright, to Lester Gardner and the other officers, the thanks and appreciation of all members for their loyal and devoted service to the Institute and to American aeronautics.

During the coming year we are to be faced with opportunities and responsibilities greater than ever before. Aviation now has become a dominant factor in national defense and is rapidly becoming an important factor in national and international commerce. There is no other single factor in our day that is so influencing the lives of men and the destiny of nations. We, the members of the Institute of the Aeronautical Sciences, are playing a most important role in this new era of air development, a role demanding the maximum of effort from every individual and every organization. Other nations have recently concentrated much of their scientific and industrial resources on the development of air power. Aeronautical research laboratories abroad have been greatly expanded. Commercial air lines are being extended to all portions of the earth and military aircraft production has reached an unprecedented stage.

We of the Institute are not working with a science that is more or less static, whose possibilities have to some extent been exhausted. Already the indications are clear that, far from reaching the end of the road to further improvements, we have not even reached the midpoint.

The future holds much promise. Recent investigations indicate the possibilities of stabilizing the boundary layer and increasing the extent of smooth laminar flow over the surfaces of wings and fuselages, with resulting reductions of drag to one-half or one-third the present value. The possibilities of boundary layer control in this field have only been partially explored. Are we to be satisfied with our present efficiencies of aircraft propulsion? Present indications suggest the possibility of substantial improvements in this field. Will our aircraft engine designers and engineers through research and development provide equipment best coordinated with the use of ideal aerodynamic forms? Have we reached the ultimate in the design of wing sections? What possibilities are there for utilizing the present waste heat of aircraft engines? These and many other fundamental problems confront the members of this Institute, if we are to develop the airplane to its highest efficiency. The picture has changed in the past year. The present demand is for bombing airplanes with speeds in excess of 300 miles an hour, and for pursuit airplanes with speeds in excess of 400 miles an hour. Progress made along these lines will assuredly benefit commercial as well as military aviation. Recognizing these facts we can predict with certainty large increases in the importance and magnitude of the aeronautical industry within the coming year.

We may further anticipate in the immediate future the most critical period in the history of the Institute. There will be large increases in the membership and in the services to be rendered.

Dr. George W. Lewis, newly elected President, I. Ae. S.

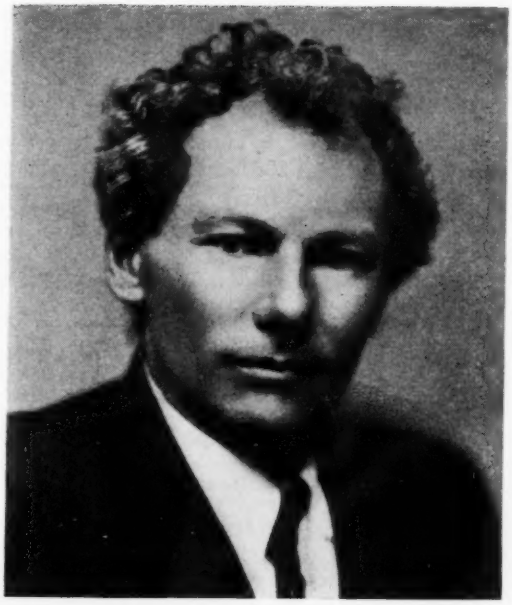
The present time therefore seems most appropriate to remind ourselves of the aims of the Institute—to promote the application of scientific knowledge in the development of aircraft; to encourage and recognize outstanding professional work; to provide incentives for the investigation and solution of aeronautical problems. With these objectives in view, the future progress of the members individually, as well as of the Institute of the Aeronautical Sciences as a whole, is assured.

In conclusion, I cannot emphasize too strongly that the prospects for the future are bright. It is within the power of this group, the members of the Institute of the Aeronautical Sciences, to grasp this opportunity to build the future history of aeronautical progress in the United States. Let us all, through mutual cooperation and common effort, make the most of this great opportunity.

Presentation of the Sylvanus Albert Reed Award

Dr. J. C. Hunsaker told of the work of A. V. de Forest, who was awarded the Sylvanus Albert Reed Award for 1938.

This beautiful testing method devised by Professor de Forest is well known to this audience, which includes the engineers whose professional reputations are being saved every day by the elimination of defective parts before the brutal test of actual flight service. Calculations of safety are based on the strength properties of sound materials and it is a poor alibi for an engineer to blame an unexpected failure on a suspected part. de Forest's magnetic test, applied in advance, removes one large element of doubt.



Prof. A. V. de Forest

The routine application of the magnetic test to ferrous materials during the process of manufacture discloses dangerous grinding cracks and defects in castings, forging, and welds. Repetition of the test at times of overhaul eliminates parts showing fatigue cracks which might develop to failure before the next overhaul.

The contribution to safety and, likewise, the cost-saving in manufacture is obvious.

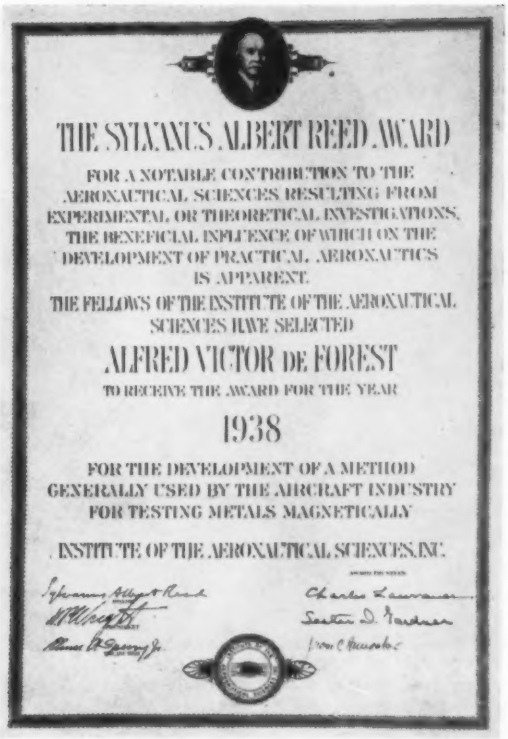
That iron particles tend to collect about small cracks in magnetized metal was discovered by W. E. Hoke in 1918, but it was not until 1928 that practical use was made of this fact. In this year, de Forest developed means for passing heavy currents around the part and the resultant high degree of magnetization greatly augmented the collection of particles. He also evolved special iron powders for use in revealing invisible cracks.

de Forest's method is used not only by the aircraft industry, but also by the more enlightened railway and automotive shops. Equipment has been supplied to England, France, Germany, Australia, Japan, China, and South America.

Professor de Forest is a Professor of Mechanical Engineering, who directs a laboratory devoted to Dynamic Strength, and teaches graduate students specializing in this field. The measurement of stress and strain in actual machine parts under operating conditions is his life work. His work with a scratch instrument for recording strain in autogyro rotors, airplane propeller blades, etc., has more recently led to the use of electrically-strain-sensitive carbon elements, as reported in our Journal.

His professional work as an engineer began with his graduation thesis from M.I.T., a brilliant and ambitious project to measure the thrust in flight of an early Burgess seaplane (1911–12). With Luis de Florez, a crude recording gear was installed to measure, and it did measure thrust, revolutions, and air speed. The value of such measurement was not appreciated at that time as the thrust was OK if the plane would fly, and not OK if it couldn't. It was not until many years later that the necessity for such measurements was felt.

He was awarded the Dudley Medal of the Society of Testing Materials and the Longstreth Medal of the Franklin Institute.



THE SYLVANUS ALBERT REED AWARD

FOR A NOTABLE CONTRIBUTION TO THE AERONAUTICAL SCIENCES RESULTING FROM EXPERIMENTAL OR THEORETICAL INVESTIGATIONS, THE BENEFICIAL INFLUENCE OF WHICH ON THE DEVELOPMENT OF PRACTICAL AERONAUTICS IS APPARENT.

THE FELLOWS OF THE INSTITUTE OF THE AERONAUTICAL SCIENCES HAVE SELECTED

ALFRED VICTOR DE FOREST

TO RECEIVE THE AWARD FOR THE YEAR

1938

FOR THE DEVELOPMENT OF A METHOD GENERALLY USED BY THE AIRCRAFT INDUSTRY FOR TESTING METALS MAGNETICALLY

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

Latham G. Reed, the brother of Dr. Sylvanus Albert Reed, who endowed the award with a bequest of $10,000, presented the award and a check for $250 to Professor de Forest.

Acceptance by Professor de Forest

I wish to thank the Fellows of the Institute for selecting my work as worthy of the Sylvanus Albert Reed Award, to thank Mr. Latham G. Reed for the presentation, and Dr. Hunsaker for his introduction.

It is useless, and would be ungracious to disguise the pride and pleasure which this award brings with it. However, a great part of my satisfaction comes from sharing the honor with those who have made the work possible.

The Institute fills an important need. There flows from an association of fellow workers an esprit de corps and encouragement, and an inspiration, which carries the capacity of each individual to a far higher level than is possible from his own unaided ability. It is our most valuable privilege to partake of this inspiration, and a welcome duty to carry it to others, according to our several opportunities.

Presentation of the Lawrence Sperry Award

Lloyd Espenschied of the Bell Telephone Laboratories told of the work of Russell C. Newhouse who was the recipient of the Lawrence Sperry Award for 1938 for his development of the terrain clearance indicator.

I will tell you briefly what this radio altimeter device is and the part played in its development by my associate, Russell C. Newhouse.

Mr. Russell C. Newhouse

THE LAWRENCE SPERRY AWARD
FOR A NOTABLE CONTRIBUTION MADE BY A YOUNG MAN TO THE ADVANCEMENT OF AERONAUTICS
THE BOARD OF AWARD HAS SELECTED
RUSSELL CONWELL NEWHOUSE
TO RECEIVE THE AWARD FOR THE YEAR 1938
FOR THE DEVELOPMENT AND FIRST PRACTICAL APPLICATION OF THE TERRAIN CLEARANCE INDICATOR
BOARD OF AWARD
INSTITUTE OF THE AERONAUTICAL SCIENCES

Imagine a plane in flight continually projecting down beneath it to the earth a beam of very short radio waves. It is not a narrow beam, but a wide one, such as will insure that a part of it always engages the earth, irrespective of the "attitude" of the craft. The earth has the property of reflecting back a portion of this beam with more or less effectiveness, depending upon the physical character of the terrain, but always enough to give a positive indication back on the plane. The echo waves are compared with those outgoing; and the time that it took for the transit to the earth and back, which is a measure of the distance, is continually indicated on a meter calibrated in feet. In other words, the plane carries with it an inertialess electrical probe that continually sounds out the distance to the earth and displays the result before the pilot.

We obtain our first glimpse of Mr. Newhouse as a student at Ohio State University in 1929. There, at the suggestion of his professor, William L. Everitt, he and some fellow students undertook some preliminary experiments upon this method and they were reported upon in his thesis. But the radio art did not then afford the instrumentalities necessary for accomplishing the result in a serviceable way and the subject was left in abeyance. Actually the general idea of this device is of many years standing, having been proposed by a number of inventors independently over a period of a decade or more. Interest in it was evidenced within the Bell Laboratories, itself, from time to time as patents issued and as the need for something of the kind was made more apparent by the flying experience of the air lines.

In the meantime, Mr. Newhouse was graduated from college and joined the staff of the Bell Telephone Laboratories, engaging in the development of aviation radio transmitters. He carried with him his interest in the radio altimeter. One of his associates in the Laboratories was Mr. Peter C. Sandretto, who soon thereafter joined the United Air Lines, becoming their radio engineer, and occasionally visited the Laboratories and discussed the matter with Mr. Newhouse. As new forms of vacuum tubes came out of the Laboratories that promised to solve the problem of the very high frequencies that are necessary, these men realized the more favorable turn of events and Mr. Sandretto persuaded the United Air Lines to express to the Western Electric Company interest in the method and to urge its development. Thus, we see the wholesome effect upon the art of a progressive operating organization. I believe Mr. Sandretto is here with us tonight and so that we may identify him I will ask him to rise.

When the laboratory development work was undertaken, the prosecution of it fell to Mr. Newhouse and a group of colleagues. The result of it we see today. The picture, then, is one of Newhouse, having been interested in this method for some years, finally being able to bring to the project enough of the up-to-date art and laboratory facilities to make it a success. It is the old story of one development being built upon a number of others.

But this really makes the picture too simple, for the process was not that of merely putting together a number of existing things, but of designing and proportioning an entirely new system. In fact, from the beginning up to the time of flight tests, it was an open question of whether the system would really work practically, because of the irregularities of the earth's surface, the variations and scattering effects that occur in the reflections. It was not a thing that could be assembled and tested out beforehand in the laboratory; there were but few measuring and testing tools at these very high frequencies. The whole thing was distinctly pioneering, the making of flight test after flight test and the perfecting of the design by additional invention, until a practical system was evolved. This is what was done by Russell C. Newhouse and his associates, and it is in honor of the accomplishment that the Award is given.

The certificate of the Award with a check for $250 was presented to Mr. Newhouse by Elmer A. Sperry, Jr., brother of Lawrence Sperry.

Acceptance by Mr. Newhouse

I appreciate very highly the honor which the Institute has conferred upon me in giving me the Lawrence Sperry Award for 1938. I hope that the future every-day performance of the terrain clearance indicator will be such that the Institute will have no cause to regret having given me the Award. I feel that I have been very lucky in having had the opportunity to work upon a device of this kind. Many engineers spend their whole lifetimes working upon devices which are undoubtedly of equal or greater importance but for which no awards have ever been established. It should be realized that a device of this type could not be developed by a lone inventor in a garret. It required the facilities which only a large company can provide; for instance, a large transport airplane was used for a period of almost a year and during a large part of the time when it was not flying, it was tied up on the ground by the changes which were being made in the apparatus installed in it. I shall always be very grateful to my room-mate of several years ago, Mr. P. C. Sandretto, now Superintendent of Communications of the United Air Lines, that when the need for the terrain clearance indicator became pressing he should have thought of and approached our organization in connection with this development.

Honorary Members for 1939

Dr. Lewis presented Honorary Membership in the Institute to Major General H. H. Arnold, Chief of the Air Corps, War Department.

Acceptance by Major General Arnold

It is particularly gratifying to me as successor of my late chief, Major General Oscar Westover to be elected Honorary Member of the Institute, and I hope in some small measure to assist in furthering the objectives of your Institute as he so effectively has done.

My association and acquaintance with Oscar Westover began as a cadet at the United States Military Academy where he preceded me by one year. At the academy on the athletic field, as a gymnast, as a cadet, his achievements foreshadowed his brilliant career.

Upon graduation, General Westover entered the Infantry and at the outbreak of the World War was serving on the Mexican Border. Incident to the rapid expansion of aviation at that time, it was necessary to secure competent personnel from other arms. In September, 1917, he was selected as the most efficient lieutenant of a large group which had been made available for transfer in order to make possible the procurement of the vast amount of supplies required by the Aviation Section of the Signal Corps. For his war services he received the much coveted distinguished service medal.

General Westover was one of the few officers of the Army Air Corps who held four ratings—balloon observer, airship pilot, airplane observer, and airplane pilot. He was selected from the Air Corps as an Army entrant in the National Free Balloon Race held at Milwaukee, Wisconsin, in 1922. He won the race by a flight of 866 miles, approximately twice the distance covered by his nearest competitor. This is one of the longest and swiftest free balloon flights on record. As a result he was selected to complete in the Gordon-Bennett International Balloon Race held in Geneva, Switzerland, in August of that year. However, on that flight luck was not with him for while flying over Hungary some peasants, believing him to be a foreign spy, seized his drag rope and pulled down the balloon. Any chance he had of winning this race thereby became nil.

He later became Commandant of the Air Corps Tactical School at Langley Field and then senior instructor of aviation at the Command and General Staff School. It is largely through his efforts and ability that the Army, through the students he taught, came to realize the importance of aviation in modern war. Subsequent events have shown the clarity of his vision. Effective December 22, 1931, he was made Assistant Chief of Air Corps, with the rank of Brigadier General, which position he held until December of 1935, when he was appointed Chief of the Air Corps. This position he held until the most regrettable accident which caused his death on September 21, 1938. Less than anyone else did General Westover realize the outstanding success in life which he attained. His innate modesty was such that each position of greater responsibility came always as a distinct surprise to him.

During his entire service, he failed to consider his own desires. As always, he wanted to go where he could be most useful. The fact that his talents were devoted for some twenty years to positions of responsibility and trust in aviation was due to the search by those in authority for competent, efficient officers. But for this most fortunate condition, the Army Air Corps would never have had his firm guidance through one of its most trying periods. That he was able to solve these problems effectively is evidenced by the position in which the Army Air Corps finds itself today. His success was realized even before his death as indicated by the innumerable tributes paid to his memory by individuals, by the national press, and by the high officers of our government. I take the liberty of quoting the remarks of the Secretary of War. "The loss of Major General Oscar Westover is the greatest in the history of the Air Corps. His services and advice were always invaluable. He has been a splendid executive and administrator during the past few years in which we have been building up the Air Corps. I cannot pay too high a tribute to his contribution to the national defense. I valued his friendship and trustworthy counsel on all occasions." General Craig, Chief of Staff of the Army, wrote "The death of Major General Oscar Westover is an irreplaceable loss to the Air Corps and to the Army as a whole. During the years he was Assistant Chief and later Chief of the Army Air Corps he developed that arm until it has become one of the greatest air forces in the world. More than any other individual by reason of his conscientious endeavor, his intense loyalty, and his clear vision, he has been responsible for the phenomenal progress of his branch in the Army of the United States. I will be acutely conscious of the loss of General Westover in the future administration of the Air Corps, as he exemplified the highest type of Army officer in ability, in training, and in his remarkable talent for transcending others in the development of the military airplane." The President of the United States paused in the steady rush of the intricate international business on which he was working at the time to himself pay a special tribute to him.

Gentlemen, let us pause for a moment and pay silent tribute to Major General Oscar Westover—a man, a leader, an officer, an aviator, a soldier.

Rear Admiral A. B. Cook sent the following telegram:

"I deeply regret my inability to be present to address the gathering and in particular to receive the Honorary Membership of your distinguished society. I realize that the conferring of this membership is an honor not to me as an individual but rather to the position I hold as Chief of the Bureau of Aeronautics. The presentation therefore becomes far-reaching for it is a testimony to your regard for the officers and civilian technicians of the aeronautical organization of the United States Navy. In their name I thank you for so signal a distinction."

Honorary Membership was given to Edward J. Noble, Chairman of the Civil Aeronautics Authority.

Acceptance by Mr. Noble

"We think that a sound approach to this problem of training private fliers is to cut in half or reduce by some other substantial

fraction the amount of dual and solo flying time now required on conventional type airplanes for a private pilot's license, provided such instruction is given in planes which will not stall or spin, which have exceptionally good visibility, and which will stay on the ground after the pilot lands them regardless of gusty or other unfavorable wind conditions.

"Such a change in the regulations would supply an immediate and tangible reward for the manufacturer who develops and markets such an airplane, because it would cut in half the time and consequently the expense of learning to fly. No manufacturer need worry about a market for such a product."

Mr. Noble paid tribute to the fine development work the manufacturers of airplanes have already done under the financial and other handicaps they face. Yet, he said, analysis of the accidents to private flyers from 1934 to 1938 showed that of the 690 fatal accidents in that period, 426 involved stalls or spins or both.

"If it is possible," he said, "to build an airplane that will not stall or spin regardless of the pilot's mistakes in flying technique—and I have been assured by competent designers that it is—it seems to me a matter of elementary logic that 426 of these fatal accidents might have been prevented on the drafting boards where the airplanes involved originated."

Of those who say that pilots would kill themselves some other way if stalls and spins were eliminated, Mr. Noble said,

"To my mind, that is as silly as it would be to contend that it is useless to vaccinate our children against smallpox and innoculate them against diphtheria because they will die of some other disease anyway."

He also said the Authority is giving serious consideration, both as a safety measure and as a sound promotional step, to requirements that the performance characteristics of airplanes be more accurately stated by the manufacturer than they have been in many instances in the past.

"As a motor boat owner," he said, "I can testify that the aviation industry enjoys no monopoly on this evil. But I need not tell this group that lack of performance on the part of an airplane bears a far closer relation to safety than the failure of a 35-mile-an-hour runabout to make more than 30 miles an hour unless it happens to find a strip of water with a decided down hill slant. If a plane owner is silly enough to attempt a take-off or landing within an inaccurately advertised distance for his particular type of ship and the field does not happen to be that long, the results are very likely to be disastrous."

He described the Authority's program for training properly 20,000 pilots as only seemingly spectacular. He asserted it was well justified by a careful study of the problem, which study would be tested by the smaller program for about 330 students now getting under way.

Dr. Lyman J. Briggs, Director of the National Bureau of Standards, was made an Honorary Member of the Institute.

Acceptance by Dr. Briggs

The great improvement in the aerodynamic efficiency of our airplanes in recent years is the direct outcome of painstaking wind-tunnel research. The study of the boundary layer, which at first seemed to be highly theoretical, is now generally recognized as of great practical importance.

The time has now come when increased attention should be given to other branches of aeronautics. Research is needed to develop structural designs and methods of fabrication that will utilize more fully the inherent strength of the material used. This provides a way to reduce weight without loss in strength. The possibilities of new light alloys should be thoroughly explored, including the magnesium alloys. A great opportunity lies ahead for the development of better fuels. The study of lubrication and lubricating oils presents untold possibilities. These are lines of research that with adequate support will pay big dividends in practical results.

Dr. Lewis presented the certificate of Honorary Membership to Commander F. W. Reichelderfer, Chief of the U.S. Weather Bureau.

Acceptance by Commander Reichelderfer

During the last few years under the leadership of Dr. Gregg the Weather Bureau service has expanded greatly, principally in the field of airways weather service; in the next few years it must extend its services much further to meet the ever increasing demands of the aviator, the farmer, the business man, and the general public.

Aeronautics and meteorology are inseparable companion sciences and it is not only a personal pleasure but a great honor to be associated with our distinguished colleagues here; it is also gratifying to the meteorological profession to be so recognized.

Every person here knows that the shallow layer of air next to the ground in which we normally live is almost an infinitesimal part of the vast atmosphere which enters into the formation of our weather. The use of surface observations alone to describe and forecast the weather is like trying to tell what is inside a melon by looking at the skin. Sometimes you can guess right, many times you are wrong. To tell accurately what is inside it is necessary to sample the melon. The Weather Bureau early recognized the necessity for "sampling" the upper air—the necessity for three dimensional study of the weather. Almost 50 years ago it began a systematic study of the upper air by means of kites. One of the early pioneers in that work was my predecessor, Dr. Willis R. Gregg. He went to the Mt. Weather Observatory in 1907 and for seven years engaged in upper air research with kites and sounding balloons. Following that, he entered the aerological section of the Weather Bureau, became its head and remained there until he was appointed Chief of the Weather Bureau in 1934. Under his direction, aerological work expanded greatly and the present airways service was developed. In 1919 he was the meteorologist at Trepassay Bay for the start of the first transatlantic trip by the N.C. boats. He envisioned a system of upper air sounding stations over the country which would give us accurate and detailed knowledge of the upper air and its vast part in the making of the weather. That system is coming closer to realization with the recent development of the radio-sonde, which consists of a small balloon and instrument by which information of the temperature, humidity, and pressure in the upper air is transmitted by radio to the observer on the ground. With increase in these daily observations over land and sea we shall have the basis for a more thorough knowledge of the general circulation of the atmosphere and can solve many problems which now confront us in the analysis and prognosis of daily storms.

It is inconceivable that meteorology, which must have been one of the first sciences to force itself to the attention of man, will be the one science that fails to yield to modern scientific attack. The demands of the aviators have already forced advances in the science and now other interests are insisting on expansion which must lead to further advances. A knowledge of future weather is indispensable to successful planning which is the order of the day, including economic planning.

The extension of forecasting is a real problem, but it is of such tremendous economic importance that it is being attacked with vigor on numerous fronts. The future only can tell what success will be attained.

Presentation of Fellowships

Dr. Lewis requested Mr. Wright to present the Fellowships of the Institute.

Group Captain Pirie accepted the Honorary Fellowship for D. R. Pye, Director of Scientific Research of the British Air Ministry.

George J. Mead was presented with Honorary Fellowship. The ten Fellows whose names appear in the account of the Annual Meeting of the Institute were then called to the speaker's table and Mr. Wright gave them their certificates, telling of their particular achievements.

The election of seventy Foreign Fellows listed in the account of the Annual Meeting of the Institute was announced and Air Commodore Stedman, Chief Aeronautical Engineer of the Royal Canadian Air Force, accepted for them.

Acceptance by Air Commodore Stedman

The development of aeronautical science has been and is still a cumulative international effort. Workers in different countries freely exchange information and ideas, and in this way they have gradually built up the impressive mass of knowledge which forms the aeronautical science of today.

The first practical power driven heavier-than-air aircraft was developed, constructed and flown in the United States, and a few weeks ago we gathered to pay tribute to the work of Wilbur and Orville Wright, those able men who exemplify the highest type of aeronautical scientist—thorough, courageous, painstaking, persevering, and inspired. It enhances rather than detracts from the reputation of the Wright brothers, to remember that, in their efforts to design a successful airplane, they studied all available information pertaining to the work of earlier or contemporaneous workers, not only in the United States, but also in England, France, Germany, Australia, and elsewhere. Nor should it lessen our respect for Lilienthal, Stringfellow, Mouillard, Pilcher, Chanute, Maxim, Langley, and others that the Wright brothers, concluding that available information was unreliable, set out to secure, through wind-tunnel research and observation of the flight of birds, the information they required.

The modern airplane is in itself the combined effort of many workers in all parts of the world, and even the countries with comparatively small populations have contributed to the available knowledge. As a Fellow of the Institute from Canada, I am proud that the Dominion has been able from the very earliest days to continue to make its own contributions to aeronautical knowledge. I refer particularly to the work of Dr. Alexander Graham Bell and his associates, Baldwin and McCurdy, and to the work of Turnbull.

It was a particularly happy and generous inspiration which prompted the founders of the Institute of the Aeronautical Sciences to recognize the international character of their subject by making provision for the election of Fellows not only from United States citizens but also from the citizens of other countries.

In this way, in honoring individual merit and gracefully acknowledging the contributions of workers in other countries, the Institute honors itself and enhances its reputation, at home and abroad, as a great Institute of aeronautical science.

President Lewis expressed the appreciation of the Institute to the Works Progress Administration for its assistance in preparing the aeronautical index for the Institute, and asked Corrington Gill, Deputy Administrator of the W.P.A., who was one of the guests of honor, to accept the thanks of the members for the continued cooperation in this important contribution to the advancement of aeronautics.

Colonel Frank P. Lahm gave the closing address.

The Wright Brothers as I Knew Them

It was my pleasure to know the Wright Brothers in the earliest days of the Air Corps, though my first meeting was entirely unofficial and in no way connected with the service. In the summer of 1907, while recuperating from a long illness, I was lying in one of those beautiful gardens at St. Germain, outside Paris, when my father walked in the gate with Wilbur and Orville Wright and there began a friendship that was to continue for many years.

It may be interesting to know how my father knew the Wright Brothers. It is a rather long story, but briefly put, is as follows: In December, 1905, while living in Paris, he heard a report that the Wright Brothers of Dayton, Ohio, had actually flown in a heavier-than-air machine. He cabled to a relative in Ohio, as follows: "Verify what Wright Brothers claim, necessary go Dayton, prompt response cable." The message was forwarded and delivered in Chicago in the night, but was a puzzle. However, my uncle vaguely recalled having heard of the Wright Brothers and their flying machine in Dayton; so he wired and eventually visited them in Dayton, interviewed witnesses of the flights, talked at length with the Wright Brothers and made a full report in writing to my father in Paris. This report was presented at a meeting of the Aero Club of France, but it fell on skeptical ears, although it did lead to a violent discussion lasting late into the night. My father then published the report in the Paris edition of the New York Herald where it was given the leading "Flyers or Liars." This led to more discussion, more doubts, but did lead to a direct contact with the Wright Brothers. So it was natural that when they came to Paris in the summer of 1907, he should see them and learn the facts first hand.

Washington, 1908

My next meeting with the Wright Brothers was in Washington. Having been detailed to the Signal Corps for aeronautical duty in September, 1907, and directed to make not to exceed two visits to London and Berlin for the purpose of investigating aeronautics, I complied with my orders, extending my investigations to Brussels, and Frederichshafen as well, then reported to the Chief Signal Officer, General Allen, in Washington the last of 1907. He directed me to report to Captain C. deF. Chandler, in charge of the Aeronautical Division of the Signal Office, which he had organized on August 1st of that year.

Signal Corps Specifications

On December 23, 1907, invitations were sent out by the Chief Signal Officer for bids for a heavier-than-air-machine of the following specifications: carry two persons having a combined weight of 350 pounds, sufficient fuel for a flight of 125 miles, remain continuously in the air for an hour with two persons during which time it must be steered in all directions without difficulty and at all times under perfect control and equilibrium, after which it shall return to the starting point and land without any damage that would prevent it immediately starting upon another flight; have a speed of 40 miles an hour in still air with a bonus of 10 per cent for every additional mile made up to 44 and a reduction of 10 per cent of the purchase price for every mile below 40, but below 36 it would be rejected. The machine was to be accepted only after successful trial flights, including prescribed tests of its speed, endurance and all other requirements of the specification. Three trials were to be allowed for speed and three for endurance, and both tests, the expense of which must be borne by the manufacturer, were to be completed within 30 days after delivery of the apparatus. The machine should be quickly and easily assembled and taken apart and

packed for transportation in army wagons and then reassembled on the field and put in operating condition in about one hour. It should be able to ascend or descend in any country encountered in field service, landing without requiring a specially prepared spot and without damaging its structure. The starting device should be simple and transportable and another device should be provided to permit safe descent in case of an accident to the propelling machinery. The whole machine should be sufficiently simple to enable an intelligent man to become proficient in its use within a reasonable time, and the price of the machine must include the instruction of two men in its handling and operation.

The general dimensions were to be determined by the manufacturers, who must submit with their proposals:

(a) Drawings to scale showing the general dimensions and shape of the machine they propose to build; (b) the speed for which it is designed; (c) total surface area of the supporting planes; (d) total weight; (e) description of the engine used for motive power; (f) material of which the frame, planes, and propellers were constructed.

Proposals Submitted

On February 1, 1908, we opened the bids in the Office of the Chief Signal Officer and found the results not only interesting but in many cases highly amusing. One man sent in a rough sketch on a piece of wrapping paper and said his machine would comply with the specifications. Many were unable to meet the requirement of enclosing 10 percent of the purchase price. One of those who failed wrote "Where there is money there are no brains, and where there are brains, there is no money." He presumably came in the latter class.

Of the many proposals received, three appeared reasonable and were accepted by the Board: one from Mr. Scott of Chicago who offered to build an airplane complying with the specifications for $1,000.00; one for $20,000.00 from Mr. A. M. Herring of New York who had done a considerable amount of experimenting and claimed he had already made numerous flights. The third, for $25,000.00, was from the Wright Brothers. Mr. Scott replied that he appreciated the honor of having his bid accepted but that he could go no further as he was unable to finance the construction of his machine. The failure to deliver the Herring machine is a long and amusing story that I will not go into here.

Fort Myer, 1908

In due time the Wright Brothers appeared in Washington to arrange the details and select a place for the demonstration of their machine. The drill ground at Fort Myer was decided upon, a shed was erected, the pylon and starting track were set up at the upper end of the field and late in August, Orville arrived with the machine and his mechanic, Charley Taylor. Here began an intimate association with Orville which was to continue through the daily tuning up flights lasting to September 9th, when I had the thrill of my first ride, lasting about 6 and a half minutes. Major Squier of the Signal Corps was taken up as a passenger a few days later, followed on September 17th by my friend and associate Lieutenant Tom Selfridge, U.S.A.

This flight terminated in an unfortunate accident in which Mr. Wright was very seriously injured and Lieut. Selfridge lost his life, the first of many victims who were to sacrifice themselves in the advancement and perfection of the airplane. We put Mr. Wright in the hospital at Fort Myer where he lay for some weeks under the devoted care of his sister, Katherine, who came on from Dayton immediately. In my frequent visits to the hospital I came to know and appreciate the sterling character of this third member of the team who was with them through the vicissitudes of those early days, sharing their hopes and disappointments.

Fort Myer, 1909

The following summer both Wilbur and Orville Wright came to Fort Myer with a new machine followed shortly by Katherine, the program of the preceding summer was resumed and carried to a successful conclusion.

By this time public interest was aroused to such an extent that every afternoon large crowds visited the field. Prominent visitors were numerous, including President Taft, members of the cabinet, foreign ambassadors and military attachés, and many other prominent people of the capital.

The Wright brothers had come to Washington to complete their contract with the Signal Corps and deliver their machine. The 1909 airplane with its maximum speed of 42 miles per hour was not so maniable in the high winds which mean so little to our present day machines with their normal speeds of 180 to 250 miles an hour. Flights were made only in light winds and while large crowds and high officials were often disappointed, the Wrights were adamant in their decision not to fly unless conditions were just right.

For the speed tests we set up a series of small captive balloons over a five mile course from Fort Myer to Alexandria and on July 30, Lieut. Foulois as passenger accompanied Orville Wright on the round trip over this course to determine the official speed. We of the board and Wilbur stood on the ground during the take-off, watched the machine disappear over the treetops to the south, and then waited in suspense for it to reappear. Wilbur, with a stop watch had accurately calculated the exact moment at which he expected to see the machine reappear coming out of the south, and when it failed to do so, he as well as the rest of us passed a very uneasy few moments until at last it came in sight and landed safely, to the cheering of the large crowd of spectators. Then began the endurance test in which it was my pleasure to ride with Orville, 1 hour and 12 minutes, a world's record at that time for two passengers.

College Park, 1909

But the contract was not completed until two Army officers had been taught to fly. Lieutenant Frederick E. Humphreys, Corps of Engineers, and myself, were designated. As the drill ground at Fort Myer was too small, we searched the country for a larger and more suitable field. Many offers were made and many sites were visited, but all were rejected by the Wright Brothers as not meeting the requirements. One day while making a balloon ascension from Washington, I passed over College Park, Maryland, saw a likely looking level field, later visited it on the ground, and eventually it was rented from the owners and became our training ground. On October 5th we moved in, built a shed for the machine, set up the pylon and track, and Wilbur began our pilot training. At the end of about 3 hours' dual we were turned loose and made our first solo flights. A few days later, I was even considered qualified to carry passengers and did so, taking Lieut. Sweet of the Navy as my victim for a flight around the field.

Wilbur was a patient and understanding instructor, always ready to explain anything we did not understand, always ready to help us, to make easy our venture into this new field which was not any too well understood by anyone at that time. Between flights and in the evening, we had long talks on aviation in general, on the Wright machine in particular, on the future of aviation and flying, and while we had great confidence in its future, I admit that in our wildest dream, we did not foresee the speed, safety, carrying capacity, and long range of the 1938 type of airplane.

Dayton Celebration, 1909

My first visit to Dayton and the Wrights' home came in 1909 when I accompanied General Allen, the Chief Signal Officer, to a two-day celebration in which the nation, the state, and the city vied in showing their admiration and enthusiasm for the two pioneers of flight. Speeches, dinners, bands, parades, and finally the presentation of three medals; one from Congress presented

by General Allen, one from the State of Ohio presented by the Governor, and one from the City of Dayton presented by the Mayor. The attitude of the two brothers was typical throughout the two days. Their pleasure, their appreciation were plainly apparent, but above all was their modesty which might have deserted them under the shower of praise and acclaim, had it not been their outstanding, inherent quality.

Dayton, 1911

My next contact with the Wrights was in 1911 when it was my privilege to spend a few days as a guest at their home in Dayton. During this visit I was to have a new experience, that of piloting an airplane under Orville's instruction, equipped with wheels instead of the skids I was accustomed to. This came in good stead the following two years as three Wright machines were sent to me in the Philippines where I used them in giving flying instruction to officers of the Army in 1912 and 1913. The 1911 visit was perhaps the highlight of my association with the Wrights and the one on which I look back with the happiest memories. It was a picture of the American home and family of which we are so proud and which fosters those qualities that produce the typical American citizen, the one who places culture, family, friends and the higher things of life above the trivial and passing interests which we are inclined to exaggerate in this age of materialism.

An Appreciation

The question was often put to me; "Which one of the two brothers really invented the airplane?" My answer is—neither one, but the two working together, checking each other, arguing out their problems step by step. Orville once expressed it when he said they would start to thrash out a question, one arguing on one side and one on the other, and before they finished they had changed sides in the argument. They approached all their problems from a strictly scientific and mathematical angle, never leaving anything in doubt and as one of them once said: "If we knew what was wrong, we could eventually find the solution." The greatest difficulty was in finding out just what was wrong. That brings back a rather amusing incident that occurred at Fort Myer during the 1909 flights. Several times the airplane was put on its cradle on the track, the motor speeded up, the weight released, the machine shot forward and left the track only to lose speed and come to the ground. Finally Wilbur and Orville left the crowd, went out on the field by themselves, put their heads together and evidently were having a profound discussion. Somewhat awed we remained at a distance to watch the proceedings, thinking it was something very serious and technical. Finally one of the brothers walked over to the machine, looked at the spark lever and saw that it had slipped back, due to lack of friction, slowing the engine down and causing the machine to lose its flying speed. It was all so simple when they found the difficulty, but I can imagine their experiments were full of just such occurrences.

The Wrights never made any extravagant claims for what their machine could do. In their first and unsuccessful negotiations with the War Department, and in the later ones which finally led to its purchase, they asked only for remuneration based on performance and were ready to demonstrate its capabilities before receiving a penny in payment.

Simplicity and order marked their procedure and their lives. The camp at Kitty Hawk was a wooden shed large enough to house the machine and their living quarters and a photograph of the interior shows it was a model of which any housewife might feel proud. At times the nights on the coast of North Carolina were cold but they were supplied with bedding. They had their own expression for temperature; that is, a "one, two, or three blanket night" depending on the thermometer reading.

No question put to them, however unimportant it might seem, failed to have careful consideration and a well thought out answer, and you may be sure we asked many questions.

As stated before, the Wright Brothers were primarily scientists, interested in the conquest of the air from a scientific viewpoint and not at all from a mercenary angle. When, in 1905 they had flown their machine sufficiently to satisfy themselves it had reached the practical stage, they stopped further work and set out to dispose of their invention, *not* to the highest bidder, but to reliable organizations or associations that would exploit it for the common good. Here was a new and revolutionary invention that was to mark the beginning of a new era in transportation, a new factor in our economic life, and while I doubt if anyone, including the Wrights, fully realized just how important it was to become and the relatively short time within which it was to prove itself, I do know that to the Wrights, it meant a great deal more than merely a means to financial success. A pertinent remark of one of them has always remained in my mind. "We want to finish up with the business end of the airplane so that we can go back to our experimental work."

Book Reviews

Air Power in the Next War, by J. M. SPAIGHT, C.B., C.B.E., edited by CAPTAIN LIDDELL HART; Geoffrey Bles, London, 1938; 175 pages, 5s.

Probably no phase of warfare has been subjected to such intense discussion as has air power. Many experts have written books speculating on the conduct of future wars. Some devote only chapters to the employment of aircraft while others use as their principal theses the strategy and tactics of this new arm. This well documented book gives a wide range of references and quotations which make it clear that the conflict of ideas on air power is no nearer unanimity than when General Mitchell was arousing public discussion.

Certain generalities are emerging, however, from the confusion of claims and rebuttals. More and more the fundamental axiom that there is a defense for every offense is being accepted as a possibility. It is still only a trend but just a few years ago the statement that there is no defense against air attack was generally accepted. Now the proponents of air power qualify their assertions that a few bombers are certain to reach their objective.

Mr. Spaight has occupied several important posts at the British Air Ministry and his writings on the laws of warfare as affected by modern developments have gained him a reputation as a conservative and well informed observer. In this book he reviews the present status of air power in the light of recent developments.

After a brief but excellent summary of the use of aircraft in the Great War he recounts the many attempts that were made to strangle air power. His studies of the use of aircraft in Abyssinia, Spain, and China are detailed and are effectively used in preparing the foundation for his conclusions.

He believes that we now face a new epoch in political and military thought. "The era of air power has begun." The author makes an interesting point regarding Spain. Without air power there would have been no civil war, but merely a mutiny, easily quelled. Bombers from Morocco brought reserve troops and protected the ships carrying General Franco's supplies.

In the chapters on "Air Power in Action" he emphasizes the difficulties armies and navies will encounter in the future. In addition to the well known functions of air tactics, military leaders will have to expect that their lines of communication, their service of supply and their ammunition factories will be under constant air attack and any retreat may be turned into a rout. Navies will not only face attack on the seas but dockyards and naval supply bases will become principal objectives.

As long as nations conduct warfare in a human manner the use of air power will not overstep the rules of civilized combat. This may be too idealistic a hope, therefore the author urges that preparation be made for the worst, while hoping for the best.

The book is one of a series on the use of the various military and naval arms in the next war and has the benefit of being edited under the direction of Captain Liddell Hart, the famous military correspondent of the Times.

Teach Yourself to Fly, by NIGEL TANGYE; English University Press, London, 1938; 166 pages, 2s.

If some publisher would reprint this book for sale in the United States at fifty cents, which corresponds to the English price, it would probably have a large sale among the hypothetical 20,000 prospective pilots who may be taking flying instruction during the next few years.

The author is one of the best known flying instructors in England and a writer of many aviation articles. His book is a course on flying instruction which he states can be used to great advantage for vicarious experiences by those who hope to fly, those who intend to fly, as well as those actually taking instruction.

He asserts that for several years before he learned to fly he read similar books and thereby reduced the time of his dual stage by one half. The book would have a strong appeal to those who wish to know how a pilot flies an airplane even though they do not expect to fly themselves. While there are many other books covering the same field this one has the appeal of brevity, clarity, and good sense.

Wings in the Night, by WILLIS S. FITCH; Marshall Jones Company, Boston, 1938; 302 pages, $2.00.

Mayor F. H. La Guardia, in his foreword to this book, says, "The thrilling experiences they encountered in night and day bombardments over the Alps, the Piave, and the Adriatic Sea made history which is now revealed to the American reading public for the first time." It therefore fills a niche in the story of American aviation participation in the World War which will be welcomed by those who are not aware of the importance of some of the units which were not on the Western Front.

The story is typical of the experiences of many college men who went directly into service. Fitch came from Dartmouth and took part in many of the bombing raids. His story of his training in Italy and of the experiences of the small group of pilots who served under Major La Guardia gives an intimate picture of life on the Italian Front. Not the least valuable part of the account are the references to the ability and leadership of Major La Guardia. With his growing stature in American politics, current historians will find much of interest in the book regarding his career on an active front.

Of particular interest is the account of the cooperation given by the American squadron to that heroic figure, Major Gabriele D'Annunzio, whose exploits in the air have become epic. The raid on an enemy airdrome north of Venice with the flying poet and later the raid on Pola, the Austrian naval base on the Adriatic, give a vivid picture of the daring work of the bombing pilots in their Capronis.

Fitch had many friends; his portrayal of their characters and loyalty, and their gradual elimination by accidents is one of the most dramatic parts of the book. No one can read the book, even at this late day, without an increased admiration for the young men who endured privations and faced danger unhesitatingly in the American Air Forces during the War.

Skyways, by CHARLES GILBERT HALL; The MacMillan Company, New York, 1938; 139 pages, $1.50.

With the recent movement for the aeronautical education of the youth of this country, many books will be published which are designed to interest young people. While this book starts as a child's book, it becomes increasingly mature with each succeeding chapter. Perhaps it was the intention of the author to catch the interest of a boy or girl, and then give them a general idea of what aviation means.

Such books should not be too critically examined, but accepted as well-meant efforts to explain in a simple fashion the history and extent of aeronautics. Though there are some small inaccuracies such as captioning an aircraft factory as a place where engines are built, and a small ten passenger airplane as a "modern air transport," the general illustrations are excellent.

In the first chapter of the book, there is a story of a legendary prince who was given advice which will even now have its appeal to aeronautical engineers. He was told that if he wanted to fly, he must wander through the Forest of Difficulty and the Plains of Discontent as that is the road for all who dwell on high.

Seventh Annual Meeting of the Institute of the Aeronautical Sciences

THE Annual Meeting of the Institute of the Aeronautical Sciences was held in the Pupin Physics Laboratories of Columbia University at 5:00 p.m., on Wednesday, January 25, 1939. T. P. Wright presided and Lester D. Gardner was Secretary.

Ralph H. Upson, E. E. Aldrin, and Jerome Lederer, the tellers, reported that 166 proxies were received in good order.

The Nominating Committee placed in nomination to serve on the Council for three years Charles Marcus, Richard Goldsmith, Raymond Haskell, and Luis de Florez. They were unanimously elected. The following were unanimously elected to serve on the Nominating Committee for 1939: J. C. Hunsaker, Charles L. Lawrance, Glenn L. Martin, Clark B. Millikan, and T. P. Wright.

The following were unanimously elected to serve on the Advisory Board for 1939: J. D. Akerman, G. M. Bellanca, Vincent Bendix, Lyman J. Briggs, R. S. Damon, C. L. Egtvedt, Jack Frye, James H. Doolittle, Hall L. Hibbard, F. K. Kirsten, Alexander Klemin, Paul Kollsman, I. Machlin Laddon, Grover Loening, Richard Mock, Earl D. Osborn, A. E. Raymond, H. J. E. Reid, E. P. Warner, and John E. Younger.

The President, Treasurer, and Secretary presented their Annual Reports.

The President's Annual Report

The Institute of the Aeronautical Sciences has now completed its sixth year. In a letter which I addressed to our members early in 1938, I indicated some of the problems then before us and some of the accomplishments which we hoped to realize by the end of the year. Although we have fallen short of accomplishing all that we hoped, nevertheless, in looking back over our activities, I feel that very definite progress has been made, both in amplifying past services to our members and in initiating and organizing new ones. Our position from the organizational standpoint is first discussed below.

Financial. We have lived within our budget, only extending the scope of our activities as funds would permit. In consequence, it is pleasing to note that we can again record having finished the year "in the black."

Membership. Our membership has increased substantially as reported by your secretary. Several additional firms have become Corporate Members, both on the East and West Coasts of the country. There are several other important firms who have not joined yet but who, after again reviewing the advantages which accrue from corporate membership, we believe will decide to become corporate members during the next year.

The new grade of "Member" has been formed and the rules for admission to the various grades of membership clarified. In addition, there have been seventy foreign Fellows selected for membership in this grade. There has been a very substantial increase in student members which is particularly noteworthy.

Constitution and By-Laws. One of the items accomplished at the first of the year was the revision of the Constitution and By-Laws to bring them up to date with practice and experience gained during the preceding five years of the Institute's existence. This included the rules governing regrading and selection of members.

Branches. Recognizing the importance of serving members throughout the country who do not have the opportunity of attending all of our national meetings, the work of organizing branches was advanced successfully.

Endowments and Awards. Present endowments and awards which the Institute administers are the following:

(1) Vernon Lynch Endowment which provides funds for the Annual Wright Brothers Lecture;

(2) The Reed Award which recognizes annually important practical achievements in aeronautics;

(3) Sperry Award which rewards the successful aeronautical effort of young men in the industry.

Plans for recognizing achievements in other phases of aviation are in the preliminary stages of organization and only await suitable endowments to permit putting them into operation.

To the members in general, the importance of the Institute can very properly be gaged by the extent of its technical services. These include the following, all of which have been expanded both in quantity and quality during the past year:

The Journal. The services of Dr. Arnold Kuethe have been acquired as Associate Editor of the Journal. The direction of editorial policies remain with Dr. Hunsaker who has served in this capacity so efficiently from the first.

I can personally well judge of the excellence of the Journal by the many favorable comments which I have received from foreign engineers and scientists concerning the articles which have appeared in it.

Meetings. In this field in particular, there has been an extension of the activities of the Institute. Meetings which the Institute sponsored or in which it cooperated were the following:

(1) Aeronautical Sessions of the Annual Meeting of the American Association for the Advancement of Science held in Ottawa, Canada, in June.

(2) Aeronautical Sessions of the Fifth International Congress for Applied Mechanics held in Cambridge in September.

(3) Repetition of some phases of the Congress for Applied Mechanics but including additional Aeronautical Sessions in Los Angeles in September.

(4) The Rotary Wing Aircraft Meetings with two days of Technical Sessions held in Philadelphia in October.

(5) The Air Transport Meeting held in Chicago in November.

(6) The Second Wright Brothers Lecture given by Dr. Hugh L. Dryden in New York on December 17th.

(7) The Seventh Annual Meeting with three days of Technical Sessions held in New York in January.

Tentative plans for one of two additional meetings are now being discussed, particularly one for the West Coast in the Spring.

Student Meetings. The tremendous interest of Student Branches in several of the large universities has been particularly gratifying. Development of future aeronautical engineers and scientists depends in great measure on the type of young men whom our universities graduate. The Institute is proud that its assistance to Student Branches, by cooperating in preparing meetings as well as through the Journal, is able to contribute somewhat toward this end. In March your President and Secretary made a general tour of the country during which a lecture covering high spots of our Annual Meeting plus a presentation of a film describing activities at Langley Field, was given to several of the student groups. We hope that this precedent can be continued in the future.

Late in the year, the idea of simultaneous sessions was suggested at which the more important papers given at National meetings could be presented at Branch meetings. A method of reproducing slides on an economical basis was worked out which makes possible the presentation of an illustrated paper by qualified proxy in almost exactly the same form as that given by the basic lecturer. This means that a lecturer of an Institute Meeting in reality presents his paper to an audience tenfold that which actually appears before him.

Aeronautical Index and Bibliographical Files. The Works Progress Administration, under the general direction of the Institute, has continued its magnificent work in the preparation of the aeronautical index and bibliographical files. I fear few of our members appreciate the magnitude of this work or its great importance. Those who have become familiar with it unanimously agree that it represents an extremely important contribution to aviation in the United States.

The Library. As indicated from time to time in the Journal, our library is gradually being built up. Plans for further expansion are under way and we wish again to offer the suggestion that individual members who have aeronautical books of which they wish to dispose, donate them to our library where they will be carefully indexed. Proper credit for their presentation will be given.

In addition to the technical services described above, the Institute has performed several other functions during the past year, some of which are:

Headquarters Activities. Our New York office has continued to serve as a point of contact for distinguished foreign visitors and Major Gardner has ably assisted such visitors in planning their itineraries and in making appointments. I can assure you that the prestige of the Institute has been greatly enhanced by this service.

Our Secretary's office is much admired by visitors, not only for the unsurpassed gallery of photographs of prominent scientists, engineers, pilots, and constructors in the field of aviation but also for the collection of museum items commemorative of important aviation happenings.

In addition to the fine work of the Secretary, I would like particularly to commend the devotion to duty of the whole office staff in performing tasks far greater than should normally be expected of them. I wish also to express deep appreciation for the work of the Membership Committee which has performed its job of reviewing the qualifications of applicants so carefully. The proper grading of members is an important but difficult task, particularly when one considers that over 500 members were admitted in 1938.

I feel that the progress made by the Institute during the past year has been satisfactory. There are other things which we want to do but can only undertake when additional funds become available. With the anticipated expansion of the industry and with the further realization by those involved of the real service which the Institute performs, I feel certain that the few remaining firms who are not now on our corporate membership list will find themselves able and willing to join.

Air expansion in the United States is to be a reality. Long range research and effective development of new types of planes, engines, and accessories is at the very root of any policy which may be adopted. An aeronautical society of a scientific and engineering nature can do much to spread information and correlate effort, thereby making itself indispensable. Our society will not, I am confident, fail in the obvious opportunity ahead of it. It has been well conceived and is now firmly established. It will, I am sure, succeed in its job.

In closing, I wish to express my appreciation for the confidence and support which I have received from the Council, the staff and the membership of the Institute of the Aeronautical Sciences.

T. P. WRIGHT

THE TREASURER'S ANNUAL REPORT

The financial statement of the Institute for the last fiscal year is very similar to the statement of last year. We have lived within our means, only spent money as it was received, and operated on a conservative basis.

The assets of the Institute have increased by $10,335 from the Vernon Lynch Fund. Two new items appear as assets valued at $1 each. The library, which now has over one thousand books, has come to the Institute principally as gifts of books. Rather than to place any appraisal value on the books, we have preferred to give them a nominal value. The same procedure is true of our Index, which has been prepared during the last three years by the W.P.A. We have it insured for $10,000 which may give some idea of the value we place on it.

In the statement of Income and Expenditures we have credited one-half the dues from Corporate Members to the Journal and one-half to the Institute income. This seemed more equitable than crediting all of these dues to the Journal as was done last year.

Members may be interested in knowing how the Institute has grown as indicated by its financial statements. I have had a comparative table prepared which gives the financial career of the Institute.

	Total Assets	Total Income	Total Expense
1933	$ 1,176.92	$ 3,572.00	$ 2,866.99
1934	7,717.18	19,223.04	15,757.41
1935	6,338.22	18,316.14	17,853.66
1936	20,906.90	23,546.78	23,285.35
1937	23,497.66	29,061.39	28,653.25
1938	35,776.91	36,147.73	35,865.80

As will be seen from this year's financial report our assets consist of restricted endowment funds and a small amount of reserves.

Our income is from dues from members and Corporate Members, subscriptions to the Journal, and miscellaneous items. $21,009.13 of our income is spent in publishing the Journal and $14,856.67 is spent in maintaining an office, a staff, and for the general activities of the Institute.

These figures are presented to the membership so that they will understand why the Institute can only undertake a modest program when compared to that of the large engineering societies, or until its income increases. So that members will have some idea of the comparative budgets of the Institute and two of the engineering societies, I will give a few figures from the 1938 financial statements of The American Society of Mechanical Engineers. Its assets are $878,187.99, or 25 times those of the Institute. The cost of A.S.M.E. activities are $405,782.40, or eleven times those of the Institute. The receipts from advertising in their publications amounts to $115,710.26. The income from publication sales is $61,786.38. As will be seen, about half of the income is derived from publishing activities.

The Society of Automotive Engineers statement of 1937 (the latest published) shows assets of $265,685.94, or seven times those of the Institute. The S.A.E. expenses were $244,617.29, or seven times those of the Institute. The S.A.E. received from advertising $123,545.00 or one-half of its income.

When the above comparisons are noted, members of the Institute will, I am sure, feel that the Institute is covering a wide field of activities with a comparatively small budget. It will also show members who make requests for funds for special purposes how necessary it is to proceed cautiously.

From observations of the financial management of the Institute for the past two years that I have been Treasurer, I can say that it has been operated on a conservative and a sound business basis.

ELMER A. SPERRY, JR.

Annual Balance Sheet as of September 30, 1938

ASSETS

Cash on Hand and in Bank		$ 269.69
Accounts Receivable		558.66
Investments of Unrestricted Funds		
The Benefactor Membership Fund: U.S. Treasury Bonds at Par Value (Market $6,230.63)		6,000.00
Investments of Restricted Funds		
The S. A. Reed Fund: U.S. Treasury Bond at Par Value (Market $10,384.38)	$10,000.00	
Accrued Interest Receivable on Bond	11.98	
Cash on Deposit for Award	285.35	
Total S. A. Reed Fund		10,297.33
The Lawrence Sperry Fund: U.S. Treasury Bonds at Par Value (Market $3,115.37)	3,000.00	
Accrued Interest Receivable on Bond	3.60	
Cash on Deposit for Award	302.38	
Total Lawrence Sperry Fund		3,305.98
The Vernon Lynch Fund: Melville Shoe Corporation (Market $9,848.75)	5,062.50	
Peoples Drug Stores, Inc.	5,272.50	
Total Vernon Lynch Fund (Value December 30, 1937)		10,335.00
Office Furniture and Equipment	7,248.79	
Less—Reserve for Depreciation	3,361.85	3,886.94
Library—Books		1.00
Aeronautical Index		1.00
Prepaid Expenses		1,121.31
Total Assets		$35,776.91
(Total Assets using Market Values $36,021.04)		

LIABILITIES

Accounts Payable			$ None
Reserves			
1939 Student Dues Paid in Advance		$ 84.88	
1939 Dues Paid in Advance		360.00	
Unearned Corporate Member Dues		5,018.96	
Unearned Subscriptions		790.14	
Total Reserves			6,253.98
Restricted Funds			
The S. A. Reed Fund	$10,000.00		
Net Income of Fund	297.33	10,297.33	
The Lawrence Sperry Fund	3,000.00		
Net Income and Donation	305.98	3,305.98	
The Vernon Lynch Fund		10,335.00	
Total Restricted Funds			23,938.31
Unexpended Income			
Balance October 1, 1937, from October 15, 1932		5,302.69	
Net Unexpended Income for Year Ended September 30, 1938		281.93	
Balance September 30, 1938			5,584.62
Total Liabilities and Unexpended Income			$35,776.91

Statement of Income and Expenses for the Fiscal Year Ended September 30, 1938

INCOME

Member Dues (Net after applying $5.00 per member for Journal)		$ 2,970.27	
Initiation Fees		515.00	
Benefactor Membership		1,500.55	
Donations		406.17	
Corporate Member Dues		8,663.25	
Miscellaneous		491.74	
Income		14,546.98	
Net Income from Journal Publication (see detail below)		591.62	
Total Income			$15,138.60

EXPENDITURES

Administration, Clerical, and Accounting		$7,737.50	
Rent		882.54	
Electricity, Telephone & Telegraph		394.10	
Office Supplies, Printing, and Stationery		973.83	
Postage		714.93	
Travel and Guest Reception		1,189.66	
Library and Index		1,547.32	
Meetings:			
Expense	$3,033.33		
Less—Income	2,749.20	284.13	
Miscellaneous		400.51	
Uncollectable Accounts		142.98	
Depreciation		589.17	
Total Expenditures			$14,856.67
Net Unexpended Income for Year Ended September 30, 1938			$281.93

Detail of Journal Income and Expenses

INCOME

Corporate Member Dues and Subscriptions	$10,913.24	
Subscriptions	10,653.78	
Reprints	33.73	
Total Income		$21,600.75

EXPENDITURES

Administration, Clerical, and Accounting	$9,006.90	
Rent	882.54	
Electricity, Telephone & Telegraph	394.09	
Engraving, Postage, and Printing	9,377.76	
Travel	961.08	
Miscellaneous	386.76	
Total Expenditures		$21,009.13
Net Income from Journal Publication (to Institute Income)		$591.62

The Secretary's Annual Report

The membership of the Institute has increased during the past year as shown by the following membership tabulation:

	Foreign	*American*	*Total*
Honorary Fellows	7	8	15
Honorary Members	2	12	14
Fellows	69	82	151
Associate Fellows	114	390	504
MEMBERS	14	51	65
Industrial Members	12	138	150
Pilot Members	12	56	68
Technical Members	28	477	505
Student Members	0	957	957
TOTAL	256	2,167	2,423

Total Membership on January 1, 1938	1,961
Members elected during 1938	513
Members deceased during 1938	11
Members resigned during 1938	20
Members dropped during 1938	20
TOTAL MEMBERSHIP ON JANUARY 1, 1939	2,423

As your President and Treasurer have presented a clear general record of the activities of the year, your Secretary need only comment on the administrative work of the Institute.

With more members, more meetings, and more Branches, the work of the staff of the Institute becomes greater each year. I cannot praise too highly the loyalty, interest, and devotion of the small staff which we are able to employ. More and more they are relieving your Secretary of the detailed operations so that his time may be free to give more attention to planning and constructive work.

The Institute has been exceptionally useful to foreign visitors this year. Many who came to this country to attend the Fifth International Congress for Applied Mechanics were entertained and assisted. From the appreciative letters received from abroad, this hospitality is greatly appreciated.

Looking forward to the plans for this year, the outstanding effort will be to make the International Congress of Aeronautical Engineering to be held in September a successful event.

Again may I express my appreciation to the officers and members for their cooperation and support during the year.

LESTER D. GARDNER

The reports were unanimously approved.

The Secretary then presented the list of honors conferred by the Institute and Fellows who had been elected.

LIST OF HONORS CONFERRED BY THE INSTITUTE OF THE AERONAUTICAL SCIENCES DURING THE PAST YEAR

The *Sylvanus Albert Reed Award* for 1938 was awarded to A. V. de Forest *"for the development of a method generally used by the aircraft industry for testing metals magnetically."*

The *Lawrence Sperry Award* for 1938 was awarded to Russell C. Newhouse *"for the development and first practical application of the terrain clearance indicator."*

The Wright Brothers Lecturer on December 17th was Dr. Hugh L. Dryden of the National Bureau of Standards.

HONORARY MEMBERS

Major General H. H. Arnold, Chief of the Air Corps, War Department.

Adolf Baeumker, Executive President, Lilienthal-Gesellschaft fur Luftfahrtforschung.

Lyman J. Briggs, Director, National Bureau of Standards.

Rear Admiral A. B. Cook, Chief, Bureau of Aeronautics, Navy Department.

Hon. Harry F. Guggenheim.

Dr. George W. Lewis, Director of Research, National Advisory Committee for Aeronautics.

Edward J. Noble, Chairman, Civil Aeronautics Authority.

Professor George B. Pegram, Professor of Physics, Columbia University.

Commander F. W. Reichelderfer, Chief, U.S. Weather Bureau.

A. H. R. Fedden, President, Royal Aeronautical Society.

HONORARY FELLOWS

Dr. D. R. Pye, Director of Scientific Research, British Air Ministry.

George J. Mead, Vice-President and Chief Engineer, United Aircraft Corporation.

AMERICAN FELLOWS

Henry A. Berliner, President, Engineering & Research Corporation.

Dr. W. G. Brombacher, Chief, Aero Instruments Section, National Bureau of Standards.

C. S. Draper, Assoc. Prof. of Aero Engineering, Mass. Institute of Technology.

Major Lester D. Gardner, Secretary, Institute of the Aeronautical Sciences.

Comdr. R. D. MacCart, Asst. Chief Engineer (Materials), U.S. Naval Aircraft Factory.

Dr. W. Bailey Oswald, in charge Aerodynamics, Douglas Aircraft Company.

Prof. Elliott G. Reid, Professor of Aerodynamics, Stanford University.

Elmer A. Sperry, Jr., Vice-President, Sperry Products, Inc.

Edward S. Taylor, Assoc. Prof. Aero Engineering, Mass. Institute of Technology.

Prof. John E. Younger, Chairman, Mechanical Engineering, University of Maryland.

FOREIGN FELLOWS

Ackeret, J., Dr.Ing.; Prof. of Aerodynamics, Zurich Technische Hochschule, Switz.

Alayrac, Antoine Charles, Lic.Sc.; Inspector General, Service de Recherche de l'Aeronautique, Ministere de l'Air, France.

Bairstow, Leonard, F.R.Ae.S.; Zaharoff Prof. of Aviation, Univ. of London, England.

Barlow, Thomas Morgan, M.S.(Eng.); F.R.Ae.S.; Director and Gen. Manager, Fairey Aviation Co. Ltd., England.

Betz, Albert, Ph.D.; Prof. and Director, Aerodynamische Versuchsanstalt, Gottingen.

Birkigt, Marc, Chairman of the Board, Soc. Francaise Hispano Suiza, France.

Bjerknes, Vilhelm F. K., Ph.D.; Prof. Emeritus, Theoretical Physics, Univ. of Oslo, Norway.

Breguet, Louis, Pres., S.A. des Ateliers d'Aviation Breguet, France.

Buchanan, J. S., F.R.Ae.S.; Deputy Director Technical Development, Air Ministry, Eng.

Bulman, George Purvis, B.S.; F.R.Ae.S.; Major, R.A.F.; Asst. Director of Research and Development (Engines), Air Ministry, England.

Burgers, J. M., Dr.Math.&Physics; Prof. of Aerodynamics, Technische Hoogeschool, Delft, Holland.

Capon, Robert S., B.A.; F.R.Ae.S.; Deputy Director of Research, Air Ministry, Eng.

Caproni, Gianni, Dipl.Ing.; Pres., Aeroplani Caproni, Isotta Fraschini, etc., Italy.

Castoldi, Mario, Dr.Ing.; Chief Engr. and Designer, Aeronautica Macchi, Italy.

Caudron, Rene, Deputy Administrator, Soc. An. des Avions Caudron, France.

Chien, Chang Tsu, S.M.inAe.S.; Commandant, Lt.-Col., Air Force Tech. School, China.

de Havilland, Geoffrey, F.R.Ae.S.; de Havilland Aircraft Co. Ltd., England.

Delage, P. A. G., Hon. Pres., Soc. An. Nieuport-Delage; Pres. Jaeger & Jaeger Aviation; Pres. Revue Scientifique, France.

Dewoitine, Emile, Managing Director and Chief Engineer, Societe Nationale de Constructions Aeronautiques du Midi, France.

Dornier, Claudius, Dr.Ing.; Owner and Head, Dornier-Werke, Germany.

Fage, Arthur, F.R.Ae.S.; Principal Scientific Officer, Aerodynamics Department, National Physical Laboratory, England.

Fairey, Charles Richard, F.R.Ae.S.; Fairey Aviation Co. Ltd.; Former President Royal Aeronautical Society, England.

Farren, William Scott, F.R.Ae.S.; Deputy Director of Scientific Research, Air Ministry, England.

Ferrari, Carlo, Dr.Ing.; Prof. of Aerodynamics, R. Scuola di Ingegneria di Torino, Italy.

Focke, Henrich, Dipl.Ing.; Director, Focke, Achgelis & Co., Germany.

Fokker, Anthony H. G., Aircraft Manufacturer, Holland.

Folland, Henry Philip, F.R.Ae.S.; Managing and Technical Director, Folland Aircraft Ltd., England.

Gabrielli, Guiseppe, Prof.Dr.Ing.; Chief Engineer, Fiat S.A., Italy.

Georgii, Walter, Ph.D.; Prof., Darmstadt Technische Hochschule, Germany.

Gouge, Arthur, B.S.; F.R.Ae.S.; Gen. Manager and Chief Designer, Short Brothers Ltd., England.

Grammel, Richard, Dr.Ing.; Prof., Engineering Mechanics, Stuttgart Technische Hochschule, Germany.

Heinkel, Ernst, Prof.Dr.Ing.; Ph.D.; Ernst Heinkel Flugzeugwerke, Germany.

Hoff, Wilhelm, Dr.Ing.; Prof., Berlin Technische Hochschule, Germany.

Kamm, Wunibald, Dr.Ing.; Prof., Stuttgart Technische Hochschule, Germany.

Kampe de Feriet, Joseph, D.Sc.; A.F.R.Ae.S.; Prof., Faculty of Science, and Director, Institut de Mecanique des Fluides, Universite de Lille, France.

Kempf, K. A. Gunther, Dr.Ing.; Chief, Hamburgische Schiffbau-Versuchsanstalt, Germany.

Lanchester, F. W., LL.D.; Hon.F.R.Ae.S.; Consulting Engineer, England.

Lapresle, Antonin, D.Sc.; Prof., École Nationale Superieure de l'Aeronautique, France.

Madelung, Georg, Dr.Ing.; Prof., Stuttgart Technische Hochschule, Germany.

Marchetti, Alessandro, A.Ing.; Managing Director, Soc. Idrovolanti Alta Italia "Savoia," Italy.

Maybach, Karl, Dr.Ing.; Director, Maybach-Motorenbau, Germany.

Mayo, Robert Hobart, M.A. (Cantab.); F.R.Ae.S.; Consulting Engineer; Technical Adviser, Imperial Airways Ltd., England.

Milch, Erhard, State Secretary, Air Ministry, Germany.

Nayler, Joseph Lawrence, M.A.(Sc.); F.R.Ae.S.; Secretary, Aeronautical Research Committee, England.

Page, Frederick Handley, F.R.Ae.S.; Handley Page Ltd. Former President Royal Aero. Society, England.

Parkin, John Hamilton, M.E.; F.R.Ae.S.; Director, Div. Mech. Engineering, National Research Council, Canada.

Pierson, Reginald Kirshaw, B.S.; F.R.Ae.S.; Chief Designer, Vickers (Aviation) Ltd., England.

Pippard, Alfred John Sutton, D.Sc.; F.R.Ae.S.; Prof., Civil Engineering, University of London (Imperial College), England.

Pistolesi, Enrico, Dr.Ing.; Prof., Applied Mechanics and Aerodynamics, Royal Univ. of Pisa, Italy.

Potez, Henry, Dipl.Ing.; Administrator, Soc. Nationale de Constructions Aeronautique du Nord; Hon. Pres., Union Syndicale des Industries Aeronautiques, France.

Relf, Ernest Frederick, F.R.Ae.S.; Supt. Aerodynamics Dept., National Physical Laboratory, England.

Riabouchinsky, Dimitri P., D.Sc.; Assoc. Director, Laboratory of Fluid Mechanics, Univ. of Paris; Prof. Theoretical Mechanics, Russian Superior Technical School, France.

Rosatelli, Celestino, Prof.Dr.Ing.; Chief Aero Engineer, Fiat S.A., Italy.

Rowledge, Arthur John, F.R.Ae.S.; Asst. Chief Engineer, Rolls-Royce Ltd., England.

Sabatier, Jacques, Ingenieur General de l'Aeronautique, France.

Schutte, Johann, Dr.Ing.E.H.; Ordtl. Prof., Technische Hochschule Berlin; Pres., Schiffbautechnische Gesellschaft e.V., Germany.

Savoja, Umberto, Dr.Ing.; Aviation Director, Fiat S.A., Italy.

Seewald, Friedrich, Dr.Ing.; Director, Deutsche Versuchsanstalt fur Luftfahrt, Germany.

Southwell, Richard Vynne, M.A.; F.R.Ae.S.; Prof., Engineering Science, University of Oxford, England.

Stedman, Ernest Walter, A.R.C.Sc.; F.R.Ae.S.; Air Commodore, Chief Aero Engineer, Royal Canadian Air Force.

Taylor, Geoffrey Ingram, Prof., Trinity College, Cambridge, England.

Tizard, Sir Henry Thomas, M.A.; F.R.Ae.S.; Rector, Imperial College of Science and Technology, England.

Townend, Hubert Charles Henry, D.Sc.; F.R.Ae.S.; Dept. of Scientific Research and Experiment, Admiralty, England.

Verduzio, Rodolfo, Dr.Ing.; Prof. Aero Engineering, R. Universita di Roma, Italy.

von Mises, Richard Edler, Dr.Ing.; Prof., Univ. of Istanbul, Turkey.

Wada, Koroku, Director and Professor, Aeronautical Research Institute, Tokyo Imperial University, Japan.

Wieselsberger, Carl, Ph.D.; Prof. and Director, Aachen Aerodynamisches Institut, Germany.

Wimperis, Harry Egerton, D.Eng.; F.R.Ae.S.; Aero Adviser to Australian Government; Late Director of Scientific Research, Air Ministry; Former President, Royal Aeronautical Society, England.

Witoszynski, Czeslaw, Prof., Aerodynamics, Warsaw Polytechnic School, Poland.

The Carnegie Institute of Technology has made an award consisting of a two-year membership in their Student Branch of the Institute, to Allan Kenneth Fink, a Sophomore of the Class of 1941, for maintaining a high scholastic record.

The Secretary announced the officers of the Institute for 1939 elected by the Council.

President—Dr. George W. Lewis

Vice-Presidents—Sherman M. Fairchild
J. A. Herlihy
J. H. Kindelberger
Robert J. Minshall
E. A. Stalker

Treasurer—Charles H. Colvin

Secretary—Lester D. Gardner

Dr. J. C. Hunsaker presented a resolution which was unanimously adopted:

RESOLVED, that the members of the Institute assembled at the Seventh Annual Meeting express their appreciation to the Officers, Members of the Council, of the Advisory Board, and of the various Committees of the Institute for their valuable services in shaping the policies and carrying out the work of the Institute during the past year.

Mr. Wright expressed the appreciation of the Institute to Professor George B. Pegram and Columbia University for the use of the facilities of the Pupin Physics Laboratories and the Men's Faculty Club during the three-day sessions.

INSTITUTE NOTES

Technical Sessions of the Seventh Annual Meeting

The following papers were presented at the technical sessions of the Seventh Annual Meeting of the Institute, held on January 25, 26, and 27 at the Pupin Physics Laboratories at Columbia University. Over five hundred members and guests attended.

Reprints of these papers are not available, and any inquiries regarding papers should be directed to the authors rather than to the Institute. As space in the Journal is available those papers selected for publication by the Editorial Board of the Journal will be printed.

WEDNESDAY, JANUARY 25, 1939

9:15 A.M. to 12:30 P.M.—Simultaneous Technical Sessions

STRUCTURES

JOHN E. YOUNGER, Chairman

L. F. ENGELHARDT, St. Louis Airplane Division, Curtiss-Wright Corporation, "Some Problems Pertaining to Pressurized Fuselages."
J. S. NEWELL, Massachusetts Institute of Technology, "The Uses of Symmetry and Anti-Symmetry."
E. E. LUNDQUIST, National Advisory Committee for Aeronautics, "On Rib Stiffness Required for Box Beams."
RALPH S. BARNABY, U. S. Navy, "Combating Corrosion in Design and Construction."
J. B. JOHNSON, Wright Field, "Materials for Airplane Construction."

INSTRUMENTS

W. G. BROMBACHER, Chairman

L. F. CARTER, Sperry Gyroscope Company, "The Gyro Magnetic Compass."
G. V. SCHILIESTETT, Massachusetts Institute of Technology, "Altitude Effects on an Uncompensated Rate-of-Climb Meter."
W. A. REICHEL and R. C. SYLVANDER, Pioneer Instrument Company, "Autosyn Application for Remote Indication of Aircraft Instruments."
R. D. KELLY and H. F. SALISBURY, United Air Lines Transport Corporation, "Correlation of Altimeter Readings in Landing."
F. G. KEAR and C. L. WASHBURN, Air Track Manufacturing Company, "Development of a Practical Inductor Compass."

1:45 P.M.—G. EMMONS, New York University, "Analysis of 8 A.M. Weather Map."

2:00 to 5:00 P.M.—AERONAUTICAL SYMPOSIUM AND DISCUSSION

J. C. HUNSAKER, Chairman

MONTGOMERY KNIGHT, Georgia School of Technology, "Education."
R. H. PREWITT, Kellett Autogiro Corporation, "Rotating Wing Aircraft."
W. F. DURAND, Stanford University, "Lighter-than-Air Aircraft."
A. D. TUTTLE, United Air Lines Transport Corporation, "Physiological Problems."
LLOYD ESPENSCHIED, Bell Telephone Laboratories, "Radio."
RAYMOND HASKELL, The Texas Company, "Fuels and Oils."

THURSDAY, JANUARY 26, 1939

9:15 A.M. to 12:30 P.M.—Simultaneous Technical Sessions

POWER PLANTS

C. F. TAYLOR, Chairman

A. M. ROTHROCK, National Advisory Committee for Aeronautics, "Effect of Air Movement on Rates of Combustion in Engines."
C. E. GRINSTEAD, General Motors Corporation, "Pressure Waves and Detonation."
E. H. OLMSTEAD and E. S. TAYLOR, Wright Aeronautical Corporation, and Massachusetts Institute of Technology, "Dynamics of Overhead Valve Gears."
G. P. BENTLEY, Sperry Gyroscope Company, "Free Vibrations of Aircraft Engines."

METEOROLOGY

D. M. LITTLE, Chairman

P. F. CLAPP and A. R. STICKLEY, U.S. Weather Bureau, "A Report on Some Further Studies of the Aircraft Icing Problem."
JEROME NAMIAS, Massachusetts Institute of Technology, "The Use of Isentropic Analysis in Short Term Forecasting."
H. DIAMOND, W. S. HINMAN, JR., A. H. MEARS, and C. HARMANTAS, National Bureau of Standards and U.S. Weather Bureau, "Improvements and Experience in Radio Soundings."
H. G. HOUGHTON, Massachusetts Institute of Technology, "On the Relation between Visibility and the Constitution of Clouds and Fog."
L. P. HARRISON, U.S. Weather Bureau, "The National Program Relating to Pressure Settings for Sensitive Altimeters."

1:45 P.M.—G. EMMONS, New York University, "Analysis of 8 A.M. Weather Map."

2:00 to 5:15 P.M.—AIR TRANSPORT

WILLIAM LITTLEWOOD, Chairman

HENRY H. KERR and F. C. FRANK, Bendix Products Division, Bendix Aviation Corporation, "The Airplane Brake."
E. R. WARNER and B. B. MASTERSON, Lockhead Aircraft Corporation, "Experimental Investigations of Tricycle Landing Gear Performance."
N. C. PRICE, Boeing Aircraft Company, "Pressure Cabin Development, Boeing Model 307."
GEORGE F. TAYLOR, Western Air Express Corporation, "Recent Trends in Airline Meteorology and Dispatching."

FRIDAY, JANUARY 27, 1939

9:15 A.M. to 12:30 P.M.—AERODYNAMICS

CLARK B. MILLIKAN, Chairman

ELLIOTT G. REID, Stanford University, "Rigorous Performance Prediction without Drudgery."
H. M. McCOY, Wright Field, "A Discussion of Propeller Efficiency."
JOSEPH BICKNELL, National Advisory Committee for Aeronautics, "The Correlation of Boundary Layer Transition Data."
L. E. ROOT, Douglas Aircraft Company, "On Control Surface Design Problems of Large Airplanes."
J. C. HUNSAKER, H. PETERS, and J. R. MARKHAM, Massachusetts Institute of Technology, "The Wright Brothers Wind Tunnel."

1:45 P.M.—G. EMMONS, New York University, "Analysis of 8 A.M. Weather Map."

2:00 to 5:15 P.M.—AIRPLANE DESIGN

B. C. BOULTON, Chairman

A. SILVERSTEIN, National Advisory Committee for Aeronautics, "Toward a Rational Method of Tail-Plane Design."
N. F. SCUDDER, Glenn L. Martin Company, "Current Progress in Methods of Flight Testing."
ALEXANDER KLEMIN, JOHN D. PIERSON, and E. M. STORER, New York University, "Introduction to Seaplane Porpoising."

Branches

The second "Simultaneous Lectures" program of the Institute Branches was scheduled for January 17th. This included the papers "Design Aspects of the Boeing 314" by W. L. Beall, and "The Curtiss-Wright 20" by George L. Page, Jr. Both of these papers were originally presented at the Air Transport Meeting of the Institute in Chicago on November 18th. The reports available from the branches indicate that the program was enthusiastically received.

At the University of Cincinnati the Boeing lecture was read by Mortimer Powell to a group of 100, including several from Wright Field. At the University of Detroit Prof. Peter Altman read both lectures to about forty students and guests. An interesting discussion followed the presentation. A previous meeting of this Branch on December 14th was opened by Prof. Altman with a short history of aviation, followed by Dr. H. L. Dryden's Wright Brothers Lecture on "Turbulence and the Boundary Layer," which was the subject of the first of the "Simultaneous Lectures" programs. The lecture was read by Prof. G. J. Higgins.

A group of about forty students of the Casey Jones School of Aeronautics heard the lectures on January 17th. A discussion followed the presentation. About fifty students and guests attended the first meeting of the recently organized Massachusetts Institute of Technology Student Branch. Prof. H. Peters read Dr. H. L. Dryden's Wright Brothers Lecture, following which there was a discussion of boundary layer flow.

At a meeting of the Los Angeles Branch on January 17th the following officers were elected: Richard S. Mock, Chairman; F. R. Shanley, Vice-Chairman; Dr. William R. Sears, Secretary and Program Director; C. Gallant, Treasurer. The Meeting was preceded by a dinner at the Hollywood Athletic Club. 94 were present at the dinner and 115 for the meeting following. The program opened with the paper "Operating Safety and Requirements of the Modern Transport" by Dr. W. B. Oswald. A. Lombard then read the Curtiss-Wright lecture. An interesting discussion followed the presentation of the papers.

At the University of Minnesota Prof. Fred Teichmann read the Boeing and Curtiss-Wright lectures to a group of about sixty. A discussion of the lectures followed. At a previous meeting on January 6th Prof. Boehnlein read Dr. Dryden's Wright Brothers Lecture. Prof. John D. Akerman then gave a short talk on the plan of the National Youth Administration to train pilots at various schools. The University of Minnesota has been chosen as one of the schools where this experimental training will take place. Announcement was made that a technicolor film "Story of Steel" sponsored by the Branch was to be shown on January 19th.

The officers of the New York University Branch are as follows: Courtney Wakefield, Chairman; Albert Horwath, Vice-Chairman; P. Colton Halstead, Secretary-Treasurer. Dr. Alexander Klemin is temporarily serving as Honorary Chairman. At a meeting on December 6th Walter Bishop of the Wright Aeronautical Corporation spoke on "Engineering Personnel and Training."

At the Polytechnic Institute of Brooklyn the Boeing and Curtiss-Wright lectures were read by Robert Kidder and Walter Dommars, respectively. About fifteen students attended the lectures, which were followed by discussions. At Tri-State College the Curtiss-Wright lecture was read by William S. Warner. The Boeing lecture will be given at the February meeting of the Branch.

Vacancy at the University of Sydney

A Public Notice appearing in the *New York Times* for February 10th invites applications for the Chair of Aeronautics at the University of Sydney, Australia. The Vice-Chancellor of the University will be in England in March and if he finds it advisable will return to Australia via America for the purpose of discussing the appointment with likely candidates. Communications should be addressed to the Universities Bureau of the British Empire, 88a Gower Street, London, W.C.1.

Personnel Opportunities

The Personnel Bureau serves individual members, as well as organizations seeking to employ aeronautical specialists. Any member or organization may have requirements listed without charge.

Available

Graduate Aeronautical Engineer with 3 years' practical experience as Airplane Structural Analyst. Familiar with C.A.A. and Army airworthiness requirements. Desires connection in east or middle west. Reply Box 81, Institute of the Aeronautical Sciences.

Available

Young man with college training and diversified aeronautical experience including personnel, flying, sales, drafting, and elementary design seeks new connection with a future. Salary secondary to opportunity. Reply Box 82, Institute of the Aeronautical Sciences.

Books Received

The Institute acknowledges with thanks receipt of the following books for the library.

Gifts of Sherman Fairchild

Jane's All the World's Aircraft, 1925, 1927, 1932, 1933, Sampson Low Marston and Company, Ltd., London.

Langley Memoir on Mechanical Flight. Parts I and II, by Samuel P. Langley, edited by Charles M. Manly; Smithsonian Institution, Washington, 1911; 308 pages.

The World in the Air, Vol. 1, by Francis T. Miller; G. P. Putnam Company, New York, 1930; 315 pages.

Gift of Otto Merkel

Wunder des Möwenfluges, by W. Schack; H. Bechhold Verlag, Frankfort a M.

Gifts of Frederick B. Thompson

Practical Meteorology for Airplane Pilots, by Frederick B. Thompson; Thompson Aviation Publishers, Detroit; 95 pages, mimeographed.

Practical Air Navigation, by Frederick B. Thompson; Thompson Aviation Publishers, Detroit, 1934; 99 pages, mimeographed.

Practical Aerodynamics for the Airplane Pilot or Mechanic, by Frederick B. Thompson; Thompson Aviation Publishers, 1938; 111 pages, mimeographed.

A Practical Study of the Airplane, by Frederick B. Thompson; Thompson Aviation Publishers, 1935; 131 pages, mimeographed.

A Practical Study of Aircraft Engines, by Frederick B. Thompson; Thompson Aviation Publishers; 50 pages, mimeographed.

Manual of Civil Air Regulations, by Frederick B. Thompson; Thompson Aviation Publishers, 1938; 65 pages, mimeographed.

Book Reviews

Untersuchungen über Grenzschichtabsaugung, by A. GERBER; Verlag AG Gebr. Leemans and Company, Zürich, 1938; 70 pages, Fr. 5.50.

Anwendung Gasdynamischer Methoden auf Wasserströmungen, by ERNST PREISWERK; Verlag AG Gebr. Leemans and Company, Zürich, 1938; 130 pages, Fr. 8.80.

These works are Communications Nos. 6 and 7, respectively, of the Aerodynamics Institute of the Eidgenossische Technische Hochschule in Zürich, and are edited by Prof. J. Ackeret, Director of the Institute.

The first publication describes experiments in which the boundary layer along the wall of a small wind tunnel is drawn away by means of various sized openings set at acute angles with the wind direction, and with the portion of the wall downstream of the opening projecting instream various distances with respect to the upstream portion. Boundary layer profiles and pressure distributions are measured. The experiments indicate that the drag of thick wing sections can be considerably reduced by drawing off the boundary layer.

In the second publication the similarity between the flow of a compressible fluid and that of an incompressible fluid with a free surface is pointed out. A considerable part is devoted to the theory of two dimensional flow of a compressible fluid. It is treated in such a way that the engineer who has had little to do with the field can readily understand it. The methods of gas dynamics are then applied directly to problems of water flow of interest to hydraulic engineers. Tables and diagrams permit the solution of specialized cases.

The Aircraft Calendar, edited by ERIC SARGENT; D. Appleton-Century Company, New York, 1939; 144 pages, $2.50.

This handy pocket size reference book, giving a fairly complete list of the airplanes manufactured in every country of the world, will be a useful directory for aeronautical engineers. Its compactness will make it easy to use. For each type of aircraft the most essential information is given. Where available, the type of engine used and the horsepower, the maximum speed and range, the dimensions, the number of seats, and the weight are given.

Of course, specialists will immediately look for the listing of such types as the English Spitfire, Hurricane, and Sunderland, and will be disappointed to find the speed a blank. In the German Section, the speed of the DO-17 and Ju-86 are missing. There is no listing at all for the Messerschmidt. An interesting list of U.S.S.R. aircraft is included. While there are many blanks, the information given is praiseworthy. In a field where there is so much secrecy required by governments, it is commendable that so much data can be published. Because there is always discussion as to the relative aeronautical positions of the air powers, a book such as this will be an indispensable aid to those interested in the subject.

Collins Aero Diary, Collins Clear-Type Press, London, 1939.

To review a diary may seem out of place in a technical Journal but this small handbook is more than what its name indicates. It contains 146 pages of useful technical data, such as, tables of logarithms, standard integrals, algebraic and trigonometric functions, etc. It also contains a brief nomenclature of aeronautics, navigational and radio data, conversion tables, engine and propeller design and performance data, and miscellaneous design and stress analysis information.

Wings to Wear, by ALICE ROGERS HAGER; The MacMillan Company, New York, 1938; 90 pages, $2.00.

Books which are intended for juvenile readers are usually so amateurish as to be hardly worth reading. Mrs. Hager has, however, managed to aim high to interest boys and girls. She has done it by the pictorial route with a minimum of text. Each page contains a picture which is described by an accurate expanded caption. Her choice of pictures wherever possible has been guided by an artistic sense. The more technical ones are splendid examples of photography. No boy or girl or grown-up who enjoys the easy flow of the presentation can fail to appreciate the extreme care taken in giving an accurate and interesting portrayal of what aviation means.

That's My Story, by DOUGLAS CORRIGAN; E. P. Dutton & Co., New York, 1938; 221 pages, $1.50.

As an inspirational book for young men, Douglas Corrigan's autobiography is excellent. It is written in the vernacular of the airport or factory mechanic. The publishers have left the grammar and conversational style uncorrected. Any boy who has health will feel after reading the story that he, too, can accomplish almost anything if he is willing to make sacrifices and has the determination.

Much of the early life of this smiling pilot whose exploit enlivened the humor of the world will be regarded as almost too uneventful. However, this intimate picture of a typical Texas home and family of small means provides the background for his flying career.

He relates how he sold papers in San Antonio, worked in bottling works, and in Los Angeles tried to become an architect by learning the lumber business. But when his thoughts turned to aviation, he spent his Sundays at a flying field taking lessons from the typical air field outfits of 1925.

The story then leads to San Diego with Ryan and the later part is too well known to repeat.

One trait of Corrigan's which is perhaps typical of many pilots was his desire to break rules made to promote safe flying. Evidently this showman complex which was so strongly developed in him made him do things which he would now know were foolish. He was lucky, but if boys who read of his many violations of regulations follow his example, they may find themselves in serious trouble.

In describing the flight to Ireland, he gives the same naive explanation of his eastward course instead of to California. The humorous Celtic excuse gave the world the smile it needed and will always give to this transatlantic episode an outstanding character.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aerodynamics

Jet Influence for Open Wind Tunnels. F. Weinig. Tunnel corrections for wing, downwash and tail-surface measurements in open wind tunnels, with regard to reaction of blower nozzle and receiving funnel, are computed for the circular jet. D.V.L. report. *Luftfahrtforschung*, October 10, 1938, pages 556–559, 4 illus., 2 tables, many equations.

Resistance to Flow through Nests of Tubes. R. P. Wallis and C. M. White. First issue—Behavior of individual rows; pressure distribution; fluid motions; pressure and velocity variations along the main stream; form drag of individual rows; and tangential drag for rectangular spacing. Second issue—Form drag of individual rows and tangential drag; staggered spacing; effect of speed; and comparison with results of other workers. Over the range of Reynolds Numbers from 10,000 to 40,000 the result of viscosity is almost negligible in the first row, and unexpectedly large in the later rows despite the highly disturbed motion there. Total drag of nest is almost wholly due to form drag of individual tubes. *Engineering*, December 9 and 23, 1938, pages 665–666 and 723–725, 13 illus., 3 tables, 3 equations.

Theoretical Discharge of Air from Ports in a Duct. W. S. Brown. Formulas are developed for the effect of friction on flow and for two methods of making the discharge quantities equal, one by varying the sizes of the ports while keeping the trunkway of constant cross-section, and the other by varying the cross-sectional area of the main trunkway while keeping the ports of equal size. An approximation to the flow through a long slot is obtained by supposing that it is composed of equal ports in series and by proceeding to the limit where the number of ports tends to infinity. Shape of a slot such that discharge velocity is uniform is calculated and width of the slot determined. Author is in the Aerodynamics Department of the National Physical Laboratory. *Engineer*, December 2, 1938, pages 610–611, 1 table, many equations.

Aircraft Design

Construction and Aerodynamics. C. M. Poulsen. Basic considerations that the aircraft builder must keep in mind, how design has progressed, and the future outlook. *Flight*, December 15, 1938, pages 550i–550l, 551, 12 illus.

Research on Stability. S. Schneider. Conditions which should fill the requirements for an airplane to be truly stable are shown by means of formulas. *Les Ailes*, November 24, 1938, page 8, 3 illus.

Variable Lift and Drag. H. A. Taylor. "The best and most recent example of a machine in which slots and flaps have been utilized to the very best advantage is the Westland Lysander. . . . So far, the Fowler flap, which is very good in theory, has not shown all its good points in practice." Five examples of flap design, disadvantages of the Fowler flap, lateral control, use of flaps for air braking, operation of the Handley-Page slotted flap, and operation of the slots and flaps on the Westland Lysander are discussed. *Flight*, December 15, 1938, pages 554–556, 6 illus.

The Work of the D.V.L. F. Seewald. Reduction in drag of modern fast aircraft in the ratio of 2:13, or by some 30 percent, seems possible, according to results obtained at the D.V.L., and this means a speed increase of about 10 percent. Drag of radiators and engine nacelles merits particular attention for reduction. Wing loading giving the maximum attainable speed at constant altitude falls away sharply with increasing height. It would be hardly worthwhile to go very much in excess of 150 kg./m.² in view of difficulties in take-off and landing. On the basis of supercharger test results, it is possible to attain constant pressure up to 10 km. altitude with a single stage, and without having to arrange for cooling of compressed air before admission to the engine.

D.V.L. tests, equipment and results referred to, or described, and illustrated cover: reduction of drag of the airplane; increase of wing loading; prospects of using propeller thrust at speeds of flight even above 800 km./hr.; determination of stresses occurring in flight; behavior of engines at altitudes; development of superchargers; development of forgeable materials having a strength as great as possible at temperatures above 580°C.; exhaust-gas turbines and methods of cooling the gas and rotor; improvement of engine performance by increase of pressure of the charge; knocking and delayed ignition; sleeve-valve engines; fuels; vibration of crankshaft-propeller system; increased durability of crankshafts and propellers; special long-range power units; atomization of fuel injected into the combustion chamber; device for taking macroscopic as well as microscopic photographs of fuel jet; navigation and various aircraft radio equipment developments; reduction of propeller and engine noises, and soundproofing; aerial photography (reference only); and effects of flying on health. *Jour. Royal Aeronautical Soc.*, Preprint for Meeting, November 17, 1938, 30 pages, 23 illus. Abstract and editorial discussion. *Flight, Aircraft Engr. Sup.*, November 24, 1938, pages 71–74, 11 illus.

Calculation of Lift Distribution over the Separate Wings of a Biplane. D. Kuechemann. Reciprocal influence of the wings of a biplane wing unit is investigated and it is assumed in general that both wings can be replaced by a vortex system conforming to Prandtl's wing theory. Additional velocities induced at a point on one wing by the presence of the other, are determined according to Biot-Savart's law, and converted into a change in angle of attack, which, as additional torsion, changes lift distribution of the wings. Lift distributions so computed for several airplane designs are compared with measured results. Goettingen Aerodynamic Institute report. *Luftfahrtforschung*, October 10, 1938, pages 543–555, 30 illus.

Determination of Lift Distribution of Non-Elliptical Wings by the Method of Successive Approximation. H. Schubert. Problem of lift distribution for any suggested wing is solved by the method of successive approximation. In this connection an estimation for Fourier coefficients of the results is derived. D.V.L. report. *Luftfahrtforschung*, October 10, 1938, pages 560–562, 28 equations.

Empirical Formulas for Airplane Performance Prediction. W. N. Hammond. Empirical formulas for the determination of some of the coefficients, parameters, and factors frequently used in airplane-design calculations, including formulas for peak efficiency condition, "best performance" propeller, and a compromise between the two, thrust horsepower available, variation of brake horsepower with altitude, maximum speed of airplane estimated without a complete performance calculation, and formula for comparing aerodynamic cleanliness of airplanes of known performance. *Aero Digest*, December, 1938, page 61, many formulas.

The Fighting Airplane—Will Multiplace Ships Challenge the "Flying Fortress"? H. J. Alter. Type of airplane required for fighting and defense would not be the small single-seater or slightly larger two-seater, but a mighty high-speed heavily-armed ship, designed primarily for high speed. Most efficient disposition of armament indicate the placement of the heavy guns in turrets in the extreme nose and upon the upper deck just forward of the tail surfaces, with secondary armament in the tail and bottom, and smaller guns in blisters or turrets along the sides.

Discussion covers: Means designer has at his disposal for increasing airplane speed; superiority of the liquid-cooled inline engine over the radial for combat airplanes; importance of the two-stroke scavenging supercharged Diesel in regard to economical fuel consumption; necessity for two engines; increase in wing efficiency (without increased drag) obtainable with the pusher propeller; location of guns for high concentration of fire in all sectors; carrying of small aerial grenades for use in bombing operations against bombers; means for securing good maneuverability and stability; supply of oxygen at high altitudes; necessity for a 7-man crew; and use of the combat airplane as a patrol ship. *Army Ordnance*, September–October 1938, pages 79–84, 4 illus.

Recent Full-Scale and Model Research on Seaplanes. H. M. Garner. "Steps which taper to a vertical edge have been used a good deal in American designs, but tests have shown that these steps have to be deeper than transverse steps for good water performance." Results of tests undertaken in a small wind tunnel and in the compressed-air wind tunnel on bodies of different shapes to see the effect on water qualities of fairing the steps. Possibilities of retractable steps, of changing steps into slopes or slants, and of assisting the action of the step when the hull is on the water by introduction of air under pressure on the planing bottom are discussed. Working rules on longitudinal stability, resulting from a few years' testing, results of measurement of local pressures on the hull, and acceleration tests are mentioned. Results of tests undertaken in a small wind tunnel and in the compressed-air tunnel on bodies of different shapes to see the effect on water qualities of fairing the steps. Vertical rear step of the Short Sunderland and its faired-in rear gun turret, and maximum pressures for the Singapore IIc are illustrated. Abstract of Lilienthal Gesellschaft paper. *Aeroplane*, November 16, 1938, pages 618–619, 5 illus.

Stress Analysis and Structures

Stability Limit of Curved Sheet Strip Stressed by Shearing and Longitudinal Forces. A. Kromm. Buckling condition for infinitely long sheet strip with constant curvature in the case of combined stresses due to shearing and longitudinal forces. It is assumed that, at the longitudinal edges, the mounting is free from moments and that the tangential displacements and transverse stresses (in circumferential direction, longitudinal stiffening with flexible bending) are eliminated. For the case of pure shear the buckling condition is evaluated and for greater curvatures an approximation formula for critical stresses is derived. In connection with the discussion of the method and results, the validity range of the compiled buckling condition is fixed. D.V.L. report. *Luftfahrtforschung*, October 10, 1938, pages 517–526, 9 illus., 49 equations.

Stress Distribution in Longitudinally and Transversely Stiffened Sheets. H. Ebner and H. Koeller. Determination of stress condition in thin-walled enclosed cylindrical shells with longitudinal and transverse stiffening by assumption of only stress bearing skin from a statically indeterminate calculation has been demonstrated in previous reports. Plane and slightly curved stiffened sheets, such as used as parts of monocoque wings and fuselages, can be treated in a similar manner.

Proper selection of static redundants ("orthogonal natural stress groups") and mathematical procedure for the most important load conditions are presented for such systems. Another report will appear shortly on verification of the method by tests on a monocoque wing model. D.V.L. report. *Luftfahrtforschung*, October 10, 1938, pages 527–542, 21 illus., 8 tables, 34 equations.

Weight Estimator. Slide rule for estimating flat materials, developed by the Dayton Rogers Manufacturing Company, will give correct weight instantly of steel, aluminum, cast iron, copper, bronze, and lead, in widths from 1/8 in. to 96 in., in thicknesses from 0.002 in. to 25 in., and in lengths from 1 in. to 1000 ft. *Aviation*, November, 1938, page 50.

Structural Design. C. M. Poulsen. Evolution of aircraft construction is surveyed and types of wing structures are compared. Parts of wing structures illustrated in drawings include those used on the following aircraft: Fairey Sea Fox, Gloster Gladiator, Saro London, Supermarine Scapa, Fairey Battle, Bristol Blenheim, Handley-Page Harrow, Short Empire and Mercury-Mayo, Armstrong-Whitworth Whitley and Ensign, American Northrop, Westland Lysander, Hawker Hurricane, Vickers-Wallis and Blackburn. Long article.

In a second article various methods of hull and fuselage construction are compared and installation difficulties with small monocoques are discussed. Drawings illustrate parts of the structure of the Saro London flying boats, Short Empire boats, Fairey Battle, Bristol Blenheim, Armstrong-Whitworth Whitley and Supermarine Scapa. *Flight*, December 15, 1938, pages 544–549 and 552–553, 30 illus.

Aircraft

CANADA

Military Norseman. For instruction of 5 or 6 pilots aboard the same aircraft, the Noorduyn Norseman has been converted to suit the requirements of the Canadian Department of National Defense. Training in the use of the latest R.A.F. navigation, bombing, signaling, and communication equipment is provided. High speed at 5000 ft., landplane, 170 m.p.h.; seaplane, 154 m.p.h. Service ceiling, landplane, 22,000 ft.; seaplane, 20,000 ft. Range with standard tanks of 105 imp. gal., landplane, 600 miles; seaplane, 550 miles. Equipment, modifications and characteristics described. *Aviation*, November, 1938, page 45, 1 illus.

CZECHOSLOVAKIA

Letov S-50 Three-Seater Observation Airplane. Letov S-50 three-seater is designed for observation but may be equipped for bombardment and reconnaissance. With two Avia R.K.-17 420-hp. engines its speed is 305 km./hr. at 1000 meters and it climbs to 3000 meters in 7 min. 30 sec. Long description of construction, equipment, armament, characteristics and performances, and two sets of three-view drawings, one showing the field of fire. *Les Ailes*, December 1, 1938, page 13, 3 illus., 1 table.

FRANCE

Airplanes in Test. Galtier 30 single-seater pursuit of wood construction and developed by the Arsenal de Villacoublay, is being tested and has shown that it will have a slightly higher speed than the M.S. 406.

The C-301 autogiro (175-hp. Salmson engine) in recent tests made a vertical descent from an altitude of 500 meters and reached the ground without rolling. Maximum speed 170 km./hr. Minimum speed 30 km./hr. Ceiling 4000 meters. Range 2 hr. 45 min. Brief references only to these military aircraft. *Les Ailes*, November 17, 1938, page 9.

The XVIth Aeronautical Show. Descriptions of the construction with dimensions and performances of the following aircraft, some exhibited at the Paris Show, and also of some engines:

First issue—Caudron "Cyclone" pursuit airplane (Renault 12-Ro.1 12-cylinder inverted vee 450-hp. engine, speed 480 km./hr., total weight 1400 kg.) having large fineness, low power and wood and metal construction. S.N.C.M. Sterna III 12-cylinder vee liquid-cooled engine giving 900 hp. at 4000 meters and 1200 hp. for take-off; Sirius 18-cylinder engine developing 1000 hp. at 4000 meters and 1300 hp. for take-off; and Algol 9-cylinder giving 500 hp. at 3000 meters and 100 hp. more for take-off, and presented in two versions, one with carburetor and one with direct injection. Amiot 350/351 derived from the 370 (powered either with two Hispano Suiza 12Y-28/29 or two Gnôme Rhône 14N-38/39 engines, maximum speed 500 km./hr. at 5000 meters, total admissible weight 11,000 kg.). S.N.C.A. Bloch 162 B-5 bomber (four Hispano-Suiza 14-AA 1120-hp. engines, speed 485 km./hr. at 5000 meters, range, 85 per cent maximum speed, 1400 to 2400 km.); and Bloch 151-2 multi-cannon attack airplane (Gnôme Rhône 14-N.21 1030-hp. engine, speed 520 km./hr. at 5000 meters). (References only to the Bloch 174 three-seater powered with two Gnome Rhone 14-N-21 engines of 2100 hp., and having a top speed of 520 km./hr. at 5000 meters, and the Bloch 135 B.4 high-speed bomber having four Gnôme Rhône 14-Mars engines of 2640 hp., transporting from 900 to 1350 kg. of projectiles at 525 km./hr. at 5000 meters over a range of 2000 km.)

Also of interest at the Paris Show (but not described) are said to be the small Fokker whirling arm demonstrating the stabilizing action of the two engines in tandem on the new attack airplane; Letourneur barrage balloons which permit a barrage at 7000 meters; United Aircraft curious system of jacks for raising vertically the half wings of Chance Vought 156; Messier front wheel, steerable and retractable, and designed for tricycle landing gear of a large bomber; and a mockup of the René Leduc stratosphere airplane, thermo-propelled and unusual with a 16-square meter surface, which should weigh two tons and, with 14,000 hp., fly at 1000 km./hr. with a ceiling of 30 km. and range of 4 hr. flight.

Second issue—Metal strips of variable thickness shown by the Société du Duralumin which are particularly adapted to aircraft construction. *Train* small 20, 40, and 60 hp. engines and a new 6-cylinder 75-hp. engine. S.N.C.A. Hanriot H-232 trainer (two Renault 6-Q.03 220-hp. engines); Hanriot H-220.1 two-seater fighter (two Gnôme Rhône 14-M 560-hp. engines, speed 505 km./hr. at 6000 meters); Hanriot H-182 trainer (Renault Bengali 4-Pei 140-hp. engine); and Hanriot N.C.-5-10 three-seater observation and cooperation airplane (two Gnôme-Rhône 14-M, or 9K, 750-hp. engines, maximum speed 350 km./hr., range 1400 km.); N.C.110 four-engined heavy bomber capable of transporting 2500 kg. over 3000 km. at an estimated speed of 550 km./hr. and having engines coupled, two together on each side of the fuselage, each group operating two tribladed concentric propellers; N.C.-1.50 high-speed bimotored bomber capable of transporting 1500 kg. over 2500 km., estimated speed being 640 km./hr. Centre-410 combat and bombardment seaplane (two Hispano-Suiza 12-Ybrs engines, range 2000 km. with a useful load of 1500 kg. at a maximum speed of 350 km./hr.). S.N.C.A. Hispano Suiza 12-Y engine on which is mounted the N.C.-C1 three-speed supercharger which maintains 920 hp. at 10,000 meters and which was developed for operation with the N.C.-110 and N.C.-150 which are designed for high-altitude flight. S.A.B.C.A. S-47 new two-seater (Hispano-Suiza 12-Y engine cannon developing 860 hp. for take-off and 835 hp. at 4200 meters) designed as a pursuit, combat, observation and attack airplane. Regnier engines. Koolhoven F.K.58 single-seater fighter (Hispano Suiza 14-AA-10 1080-hp. engine, maximum speed 540 km./hr. at 4500 meters). Consolidated Aircraft Corporation exhibit. Construction, armament, characteristics and performances are given for most of these airplanes. *Les Ailes*, December 1 and 8, 1938, pages 5–6, 8, 10 and 6–7, 9, 11, 11 illus.

Aeroplanes at the Paris Show. "The fastest aeroplane in the show was undoubtedly the Supermarine Spitfire which is good for more than 355 m.p.h. in standard form. The Lignel Mistral racer is supposed to be capable of 350 m.p.h." Power plant, dimensions, weights, and performances (in some cases) are given in a table for the forty-seven airplanes exhibited at the Paris Show. Twenty-eight were military types including eleven fighters, seven bombers, four reconnaissance airplanes, one reconnaissance flying boat and four trainers. The long-range Farman N.C.2234 can be classed either as bomber or long-range mailplane.

Three-view drawings are shown for the following single-seater fighters exhibited; 342-m.p.h. French Loire-Nieuport CAO.200 (890-hp. Hispano-Suiza 12-Y-31); the 335-m.p.h. British Hawker Hurricane (1030-hp. Rolls-Royce Merlin II); the 305-m.p.h. French Marcel Bloch 151 C.1 (870-hp. Gnôme Rhône 14 N.11); and the 312-m.p.h. Netherlands Koolhoven Fkk.58 (1080-hp. Hispano 14). The United States exhibited two aircraft, France 28, Great Britain 5, Belgium 2, Czechoslovakia 2, Germany 1, Netherlands 2, and Poland 5. Brief discussion of the Paris Aero Show. *Aeroplane*, December 14, 1938, pages 778–779, 4 illus., 1 table.

Bréguet 730 Cruiser Flying Boat. A. Frachet. Hull of the Bréguet 730 25-ton military cruiser monoplane flying boat is arranged like that of a boat and the fully cantilever wing has very good fineness. Four Gnôme Rhône engines giving a total of 4000 hp. Maximum speed 325 km./hr. at 1750 meters. Range 4500 km. Long description, characteristics, performance. *Les Ailes*, November 24, 1938, page 9, 2 illus., 1 table.

Dewoitine D-342. Dewoitine D-342 low-wing landplane can transport an important commercial load consisting of 24 passengers and 600 kg. of freight, or a total payload of 2750 kg. Three Gnôme Rhône 14-N.17 950-hp. engines. Maximum speed around 380 km./hr. Cruising speed 320 km./hr. at 65 percent power. Long description of construction, characteristics, performances. *Les Ailes*, December 15, 1938, page 9, 3 illus., 1 table.

Marcel Bloch 151-2 Pursuit Airplane. A. Frachet. Monoplane of metal is armed with two cannons and two machine guns and will be produced at the rate of 100 per month. With a Gnôme Rhône 14-N.21 1030-hp. engine its speed is 520 km./hr. and it climbs to 5000 meters in 6 min. Range 775 km. Long description of construction, equipment, armament, characteristics, and performance. *Les Ailes*, December 8, 1938, page 16, 3 illus., 1 table.

GERMANY

Exposition of the German Industry. The Dornier Do-17 was the only full-scale airplane displayed at the Leipzig Exposition, although a series of mockups were shown such as the Focke-Wulf Condor, Junkers Ju-90, Blohm and Voss 139-B and Dornier Do-26, as well as equipment and materials. A very few details of these airplanes are given as well as of the following: Siebel 104, Focke-Wulf helicopter, Arado Ar.79, Henschel H.S.-126, Klemm Kl-35 seaplane, Minimoa sailplane, Ago Kurier 192 high-speed transport, Fieseler Storch Fi-156, Heinkel 112 single-seater pursuit, and Gotha 150 two-seater; Schwartz and V.D.M. propellers; I.G. Farbenindustrie electron Hydronalium for engine mounts and crankcases. *Les Ailes*, December 8, 1938, page 15.

The Long-Distance Seaplane "Hamburg Ha139." Hamburg Ha139 seaplane designed to be launched by catapult is powered by four 600-hp. Junkers Jumo 205C engines and carries a crew of four and payload of 6.9 metric tons. Machine crossed the Atlantic on the Azores-New York route in less than 16½ hr., corresponding to an average speed of 235 km./hr. over a distance of 3850 km. in spite of strong contrary winds. Long description. *Engineering*, December 16, 1938, pages 720–721, 6 illus.

New Military Aircraft. Description of construction, armament, characteristics and performances of the following: Blohm and Voss Ha138 (1938 design) long-range reconnaissance flying boat (three Junkers Jumo 205C 600-hp. 12-cylinder heavy-oil engines, maximum speed 275 km./hr., cruising speed 235 km./hr., longest range 5000 km. Focke-Wulf Fw-58 "Weihe" (1936/38) three- to four-seater landplane for training pilots in flying two-engine airplanes as well as in radio, blind and night flying, military practice, bomb dropping, and gunnery (two Argus As-10-E 240-hp. 8-cylinder inverted aircooled engine, maximum speed 255 km./hr., range 970 km., bomb load up to 150 kg.). Focke-Wulf Fw-58 "Weihe" (1938) seaplane (same engines, bomb load and armament as the landplane, maximum speed 226 km./hr., range 870 km.). *Luftwehr*, November, 1938, pages 469–472, 8 illus., 3 tables.

Siebel Fh104 Bimotored Airplane. High-speed commercial airplane for the transport of four passengers carries a pay-load of 810 kg. Two Hirth H.M.508 170/240-hp. engines, or other engines up to 280 hp. Maximum speed 335 km./hr. Range at cruising speed of 300 km./hr. at 2500 meters, 1000 km. Long description. *Rivista Aeronautica*, November, 1938, pages 347–349, 1 illus., 1 table.

GREAT BRITAIN

The "Mercury" in Empire Service. Mayo composite aircraft has entered regular service in the mail-carrying fleet of Imperial Airways. The two machines took off at Southampton and the Mercury, carrying more than a ton of mail, after separating from the Maia set off on a nonstop flight to Alexandria. Only five minutes elapsed from the time of take-off to separation of the two machines and the Maia was being moored again within 8 minutes of the first take-off. Brief reference. *Engineer*, December 2, 1938, page 617.

Unorthodox Transport. New Cunliffe-Owen flying wing is externally reminiscent of the American U.B.14 (Burnelli), which has been used for experimental work, but the structure has been entirely redesigned. Airplane will have accommodations for 15 to 20 passengers and will be powered by two Bristol Perseus XIV.C 815-hp. sleeve-valve engines in nacelles located at the front corners of the central wing portion or fuselage. Split hydraulically-operated flaps are fitted between the central wing section, or fuselage and there is a third flap beneath the center section. Outer flaps can be operated independently of the center-section flap. Maximum speed 235 m.p.h. at 6000 ft. Maximum range 1950 miles. Long description of construction and equipment with drawings of structural features and cutaway drawing showing location of equipment. *Flight*, December 22, 1938, pages 572–575, 7 illus.

The Vickers Wellesley Monoplane and Its Geodetic Structure. Advantages of geodetic construction which permitted the use of a high aspect ratio and extra fuel tanks in the wings of the Wellesley; theories on which geodetic construction is based; details of special rolling mill patented by Vickers-Armstrong for rolling from strip the geodetic members in the form of channels of correct section and curves; and description of the Wellesley's construction with a few performance figures and dimensions. A large sectioned drawing of the Wellesley illustrates the construction and refers to a number of detail drawings showing: interior of the wing; retracting gear of the undercarriage; schematic arrangement of the center section; nose and tail structure; structure fittings; union pieces pulling the various tubular members together; and simple means of fastening the fabric to the geodetic members for heavy and light loading. Photograph of rolling mill and high-speed saw included. *Aeroplane*, December 7, 1938, pages 746–749, 16 illus. *Flight*, December 8, 1938, pages 517–523, 26 illus.

Another Long-Distance Record in Reach. Flight of 7162 miles nonstop put up by the three Vickers Wellesleys is 78 miles short of the closed-circuit record held by a Japanese airplane with 7240 miles. It is believed that the Wellesleys could fly for 55 hours at their most economical speed. Short editorial suggesting that they make an attempt on the closed circuit record while in Australia. Radio messages telling Sq.Ldr. Kellett's story of the flight, and issued by the British Air Ministry are quoted. *Aeroplane*, November 16, 1938, pages 589, 597–598. Leader's story of the flight, and details of carburetion system used with the Bristol Pegasus engines. *Flight*, November 17, 1938, page 458.

The British Aircraft Industry (and British Service Aeroplanes). "Every pertinent publishable figure for the 146 aeroplanes and 55 motors," built by 47 British aircraft constructors and 14 aircraft engine makers, are shown in tables. Photographs are given for 42 British Service airplanes with notation of engine and type of construction. Photographs and similar data are shown for 17 commercial aircraft, for 28 training and sport airplanes, and for three gyroplanes. Photographs of 25 aircraft engines are presented with a table of specifications and performances for 57. Suppliers to the British aircraft industry are listed with their products, a few of which are illustrated. Explanation of the directory is given by C. G. Grey. *Aeroplane*, November 23, 1938, pages 639–681, 638, many illus., 2 tables.

The DeHavilland Albatross. Frobisher, first of five monoplanes (four 525-hp. Gipsy Twelve engines) ordered by Imperial Airways for the London-Paris route. Carrying a crew of four, 22 passengers and 1870 lb. of baggage, mail and freight, the airplane will do the journey at over 200 m.p.h. on 55 percent of maximum take-off power and will carry fuel for a range of 435 miles. Long description, including wooden construction of the wing, fuselage, fuel and electrical systems, cabin, flying qualities, and complete specifications. Flap gear, tail units, Bakelite reinforcing plates applied to roots of span electrical and manual actuating systems for retractable

undercarriage, and recommended sleeper berth are illustrated in drawings. Cutaway drawing shows location of equipment.

Mail-carrying version of the Albatross is also described. Maximum range is 3300 miles in 15 hr. 54 min. in still air loaded to 32,500 lb. (1000 lb. payload of mails) when crusing at 210 m.p.h. at 11,000 ft. on 2100 hp. *Aeroplane*, November 16, 1938, pages 620–624, 589, 594, 595, 18 illus.

Very long detailed description of both passenger and mail versions with two-page cutaway drawing showing wing structure and layout and location of equipment. Other drawings illustrate retractable landing gear of the mail version, fuselage laminate wood construction, and cooling system. List of manufacturers of parts and materials is given. Lessons learned from the Comet are discussed. *Flight*, November 17, 1938, pages 450a–450d, 451–455, 13 illus.

Performance of Imperial Airways' latest passenger carr er and transport technique in general. Photograph of the Albatross control cabin is shown with a key to the more important controls and instruments. *Flight*, November 24, 1938, pages 470–471, 2 illus.

The Newest Formula. DeHavilland D.H.95 all-metal high-wing transport (two Bristol Perseus XIIc sleeve-valve 850-hp. engines) is nearly ready and plans have been evolved for quantity production. Accessory drive gear box for each engine is mounted on the wing spar and is coupled by a flexible drive which can be quickly detached. Details in design which simplify manufacture, tests on the undercarriage, proof-loading and destruction tests, and wing structure are described. *Flight*, November 24, 1938, page 474a.

ITALY

Stoffanatti "Canard" Airplane. Stoffanatti SS-2 "Canard" airplane is powered by a 16-hp. engine and flies at a top speed of 102.5 km./hr. It is constructed of wood and has tricycle landing gears. Two rudders mounted at the two extremities of the wing can also be used as aerodynamic brakes. A multiplace touring airplane and combat airplane have also been designed. *Les Ailes*, November 17, 1938, page 12, 1 illus.

New Military Aircraft. Fiat CR-42 single-seater braced sesquiplane. Fiat A.74 R.I.C.38 engine developing 840 hp. at 3800 meters. Maximum speed 450 km./hr. at 4000 meters. Macchi C.200 single-seater fighter. Same Fiat. A.74 R.I.C. engine. Maximum speed 505 km./hr. at 4800 meters. Short descriptions of construction, characteristics, and performances of both and armament of the Macchi. *Luftwehr*, November, 1938, pages 474–475, 3 illus., 2 tables.

U.S.A.

American Planes and Engines for Military Service. Purposes, engines, photographs, and in some cases performances and characteristics are given for 55 American military aircraft. Specifications and performances for the 53 American engines mentioned are given in a table. *Aviation*, November, 1938, pages 30–42, many illus.

Boeing Completes Test on the 314 Flying Boat. Work of 261 separate instruments was accomplished by 100 instruments, 58 of which were installed as regular equipment at the posts of various flight crew members and the other 42 installed as special test equipment. Five of the test instruments alone provided readings from 134 different pick-up points in the airplane. Readings of the various instruments were taken by periodic camera exposures, by moving picture film, and by manual tabulating. Test equipment was concentrated at six different "test headquarters" on the Clipper's flight deck, where test engineers compiled their continuous records during flights. Description of tests made. *Aero Digest*, December, 1938, pages 44, 45, 78, 7 illus. Tests discussed. *U.S. Air Services*, December, 1938, pages 21–22, 34. Photographs of test equipment in place on plane and few details of test. *Aviation*, December, 1938, pages 28–29, 9 illus.

Con Ellingston Special. Test flights have been under way at Helena, Montana, on a retractable-wing monoplane having an estimated top speed of 165 m.p.h. with wings in the extended positions. Few details, characteristics, performance. *Aviation*, November, 1938, page 45, 2 illus.

Cunningham-Hall Freighter. Developed from the PT-6 six-place cabin biplane, the Cunningham-Hall PT-6F light freighter has provision for a pay load of 1128 lb. and excellent accessibility to the freight compartment for stowing all types of bulky luggage. Airplane has a high speed of 150 m.p.h. and features quick take-off and good climb, under full load conditions, making it a practicable machine for operation from restricted areas. Single 365-hp. Wright engine. Normal cruising range 700 miles. *Aviation*, December, 1938, page 39, 5 illus.

Pre-Flight Testing Program of the CW-20 Transport. Program of construction and tests now being carried out at the St. Louis Division of Curtiss-Wright Corporation on the landing gear, the engine installation, and other sections which can be assembled as units before being attached to the airplane. *Aero Digest*, December, 1938, page 53, 5 illus.

Description of design and tests being undertaken. *U.S. Air Services*, December, 1938, pages 16–17, 36, 3 illus.

Structural details of pressure cabin and methods used in testing the engine installation, retractable landing gear, and hydraulic system are illustrated by photographs. *Aviation*, December, 1938, pages 34, 35, 8 illus.

Seversky Executive. Entirely new commercial "Executive" low-wing monoplane of all-metal construction has a retractable tricycle landing gear and Pratt-Whitney twin-row 1200-hp. engine. Fowler type flaps have been included in the design to reduce landing speed, and a stainless steel skid is provided along the belly of the fuselage for emergency landings with wheels retracted. Top speed 330 m.p.h. Cruising speed above 13,600 ft., 300 m.p.h. Range at cruising speed (extra tanks) 2000 miles. *Aviation*, December, 1938, page 37, 5 illus.

Spartan Model 7W Executive. The 7W Executive 5-place single-engined low-wing monoplane, with relatively few changes, can be converted into a military aircraft. Military airplane differs only in provision for the following armament: to fixed .30-cal. machine guns and 1000 rounds of ammunition in the nose, the guns being synchronized to fire through propeller disc, and the reserve fuel tank removed to allow space for the guns, the additional fuel being carried in the center tanks; two Type A-3 bomb racks on the wings, with a permissible bomb load of 300 lb.; folding doors and a retractable windshield in the top of the airplane for a .30-cal. flexible machine gun provided with 600 rounds of ammunition. Pratt-Whitney Wasp Jr. SB 450-hp. engine. Maximum speed (9600 ft.) 208 m.p.h. Cruising speed (9600 ft., 75 percent power) 200 m.p.h. Rate of climb 1430 ft./min. Cruising range (75 percent power) 900 miles. *Aero Digest*, December, 1938, pages 69, 70, 73, 11 illus.

Vega's First Model. Preliminary details of 5–6 place private-owner plane designed for UniTwin Power Plant by the Vega Airplane Company, subsidiary of Lockheed. Basic feature is dual mounting of two Menasco C6S4 260-hp. engines to drive a single propeller. Design is also suitable for use as a "starliner" on the new feeder routes. Estimated gross weight 5411 lb. Tricycle landing gear of retractable type. Estimated top speed in excess of 200 m.p.h. Cruising range about 1000 miles. Description. *Aviation*, November, 1938, page 43, 1 illus.

Vultee V-12 Attack-Bomber. The V-12 differs from the V-11GB principally in its streamlined canopy, which fairs smoothly into the fuselage, and in a new type counterbalanced gunner's seat which provides direct sighting over a wide range of firing angles. Standard V-12 is equipped with a Wright GR-1820 G-105A engine (900 hp. at 6500 ft.) with 2-speed blower, but is available with numerous alternate power plants. Bomb loads up to 3000 lb. can be carried, depending upon range. Pilot's armament consists of four fixed wing guns, selectively fired by electric trigger grip control on the control stick.

Maximum and cruising speeds, attack mission, 243 m.p.h. (19,000 ft.) and 218 m.p.h. (15,000 ft.), respectively, and for bombing mission 222 and 190 m.p.h., respectively. Maximum range 1200 and 2070 miles, respectively. Description, characteristics, armament, design loading for both normal attack and normal bombing missions, and performance for each of these two missions. *Aviation*, December, 1938, pages 32, 33, 1 table.

Aircraft for High Altitude Flight

Details of the Airplane Making the World Altitude Record. Caproni single-seater airplane in which Colonel Pezzi reached an altitude of 17,116 meters, attaining a world altitude record, had a pressure cabin, a metal cylinder covered by a hemispherical glass dome. Pilot used a breathing apparatus and sealed the cabin only at an altitude of 8000 meters so that the latter would only have to resist the difference of pressure existing between 8000 and 17,000 meters, or 200 mm. of mercury. Apparatus for supplying the air for the cabin is described. Controls were regulated and greased for resistance at prolonged operation at very low temperatures. The pilot encountered −50°C. at maximum altitude. The four-bladed wooden propeller with fixed pitch and very large blade surface, and the Piaggio 14-cylinder double-row engine are referred to. *Les Ailes*, November 24, 1938, page 8.

Sub Stratosphere Experiments. High altitude experimental flying has been carried out during the past few weeks by the "Laurent Guerrero," four-engined pressure-cabin Farman prototype of Air France-Transatlantique which is being prepared with two similar machines for North Atlantic experiments. On one flight the machine spent four hours at a height of 25,000 ft. Brief reference. *Flight*, Deeember 22, 1938 page 578b.

Aircraft Manufacture

Not So Different. Editorial comment on T. P. Wright's paper entitled "American Methods of Aircraft Production" which was presented before the Royal Aeronautical Society with reference to British methods of production. Paper and discussion following are also quoted. *Flight*, November 17, 1938, pages 435–436, 439–441, 3 illus.

Aircraft Alighting Gear

Something New in Undercarriages. Latest Dowty aircraft wheel with intermediate-pressure tire, can be supplied complete with brakes and built-in oleo-pneumatic shock absorber. Four designs are available covering all sizes of aircraft weighing between 6000 and 24,000 lb. Description. *Flight*, November 24, 1938, page 481, 3 illus.

New Dowty wheel and shock absorber which does away with shock-absorber legs. Travel of 18 in. can be provided for the wheel itself. Description. *Aeroplane*, November 23, 1938, page 684, 2 illus.

Undercarriages. "Unfortunate external fairings for the undercarriage characterise the Seversky pursuit used by the U.S. Army." Later developments in design technique are reviewed with a discussion of the tricycle undercarriage and the persistence of the fixed landing gear. Latest Dowty wheel with built-in oleo-pneumatic shock absorber, and new developments at the Leamington works of the British Lockheed concern are mentioned. Undercarriage of the Vickers Wellington twin-engined bomber is said to be one of the neatest large undercarriages yet seen. Illustrations include this airplane, the forward portion of the model of the new Fairey four-engined transport which will have a nose wheel of substantial proportions, retractable landing gear fitted to the Armstrong-Whitworth Ensign, the new Grumman monoplane fighter for the Navy, and a Rotax motor used in retracting undercarriages of large landplane. *Flight*, December 15, 1938, pages 563–565, 10 illus.

Air Transportation

Subsidies, Licenses, and Wangles. A sum of £100,000 has been set aside for subsidizing British internal air lines. White Paper on Civil Air Transport Services; applications for licenses to run internal air lines; a white paper on the proposed agreement between the British Government and British Airways for a London-Lisbon service; and a few particulars of the eleven companies which are named in the White paper for participation in the subsidy also. *Aeroplane*, December 21, 1938, pages 823–824.

3 Cent Air Mail? J. Parker Van Zandt. Survey of 22 European airlines. *Aviation*, December, 1938, page 22, 2 illus.

Aviation in the Holy Land. J. P. Van Zandt. International airlines serving Palestine, and Lydda airport. *U.S. Air Services*, December, 1938, pages 13–15, 3 illus.

The Fourteenth Year. Points from Sir John Reith's speech at the annual general meeting of Imperial Airways, giving a résumé of the company's work during the preceding year. *Flight*, November 24, 1938, pages 474d–474e, 5 illus.

National Socialism in Air Transport. Merger of Imperial Airways and British Airways into a public corporation is discussed. *Aeroplane*, November 16, 1938, pages 591–592. Short discussion of merger. *Flight*, November 17, 1938, page 444.

Airships

The Airship "Graf Zeppelin." New German L.Z.130 Graf Zeppelin is described in great detail, especially the structure. Apparatus has been fitted to indicate both the static charge on the airship and the electrical potential of the atmosphere surrounding it. Hull of the airship is divided up into 16 compartments for gas bags, the compartments being lined with a taut cord network to prevent the bags from coming into contact with the girders. Between network and outer hull covering is an air space acting as an insulator against the sun's rays and also assisting ventilation. Only 14 of the gas bags are fitted with automatic release valves, the smaller conical bags in nose and tail being sufficiently strong to withstand changes ing as pressure. *Engineering*, December 30, 1938, pages 751–754, 764, 18 illus., 6 on Plate XXXVI.

Balloons

Balloon Barrage. Technical and tactical problems of the balloon barrage are discussed, including: property and characteristics for a barrage balloon; question of spherical or elongated balloon form and of balloons with air pockets or dilatable balloons; effect of mooring cables on the airplane; and principal characteristics of the Ariel balloon; tactical work of the barrage balloon in the most extensive localities and over long and narrow targets or point targets. From *Bulletin des Sciences Militaires*, April, 1938. *Rivista Aeronautica*, November, 1938, pages 317–322, 9 illus.

A Balloon Barrage for Germany. An experimental balloon barrage has been raised with the object of defending the Leuna Gasoline Works near Halle, Germany. During the September crisis pilot of a civil air transport airplane is said to have flown his airplane into a balloon cable somewhere in Eastern Germany, the cable sawing into the wing up to the main spar before it broke. The machine got down, otherwise undamaged, after violent gyrations. Brief reference. *Aeroplane*, December 14, 1938, page 764.

Propellers

Airscrew Development. Progress in propeller design is traced with special reference to the variable-pitch type, and performance figures for the Rolls Royce Kestrel XVI fully-supercharged unit operating with the fixed and variable-pitch propellers, respectively, are compared. Early variable-pitch limitations are discussed. Descriptions cover: the Ratier propeller designed for use with the French engine cannon; a small windmill operating the pitch-changing mechanism; Curtiss and Hamilton designs; a number of Fairey variable-pitch propeller designs under development; the Gnôme Rhône propeller employing compressed air; the Everel; the Schwartz; Heine (Jablo); Hordern-Richmond-B.H.T.; and the Avimo wood and synthetic-resin propellers. Hamilton and Curtiss are said to be experimenting with reversible-pitch propellers for the U.S. Navy. In Italy the test pilot M. Stoppani lately demonstrated a device of this type on a Cant Z.506 seaplane. Drawings illustrate the Rotol constant-speed (non-feathering) propeller used for the Pegasus engines of the record breaking Vickers Wellesleys. *Flight*, December 15, 1938, pages 560–562, 9 illus., 1 table.

Automatically Variable. Change of pitch in the DeLavaud propeller is brought about by, and in direct ratio to, the aerodynamic thrust forces. As thrust increases, pitch decreases and vice versa. The two other forces operating on the propeller, torque (or drag), and centrifugal force, are used to balance this thrust, which is used to operate the pitch changing mechanism. Torsion bar is designed not only to take centrifugal stresses, but also to take a twisting load far in excess of that normally applied. Description of design and performance in an airplane during flight. *Flight*, November 17, 1938, pages 449–450, 2 illus.

Ratier Machine for Producing Propeller Blades. M. Victor. Automatic machine tool in use at the Ratier plant at Figeac. Long description. *Les Ailes*, November 17, 1938, page 8, 3 illus.

Miscellaneous

Behind the Scenes with the Engineers. Account of the Third National Aircraft Production Meeting of the Society of Automotive Engineers, and short abstracts of papers presented. *Aviation*, December, 1938, pages 30, 31, 72, 74, 7 illus.

British Exhibits in Paris. Four British military airplanes and twenty British aircraft engines will be shown at the Paris Aero Salon, and fifteen British firms which make accessories and components will exhibit their products. Short list. *Aeroplane*, November 23, 1938, page 633. Few details of each British engine and aircraft to be exhibited at the Paris Aero Show. *Flight*, November 24, 1938, pages 474j–474l, 475–476, 13 illus.

Rotary Aircraft. Rotating Wing Aircraft Meeting, held last month at the Franklin Institute under the auspices of the Philadelphia Chapter of the Institute of the Aeronautical Sciences. Short review of papers by R. H. Prewitt, G. P. Herrick, E. Burke Wilford, A. H. Galloway, Lt. H. P. Gregory, and W. L. Le Page. *Aero Digest*, December, 1938, pages 46, 78, 3 illus. Account of Conference by J. Ray. *U.S. Air Services*, December, 1938, page 30.

Acoustics

The National Physical Laboratory. Research on acoustics in the Physics Department is described, including objective sound meters, noise of motor horns, and noise abatement in aircraft, motor vehicles and buildings. Research on radiation and on the surface finish of metals is also reviewed with a description of a new type of colorimeter. *Engineering*, December 9, 1938, pages 666–669, 1 illus.

The Filtration of Sound. R. B. Lindsay. Compressional waves in a confined fluid medium; physical considerations of acoustic filtration in air; transmission theory of acoustic filtration (ideal infinite case) and illustrations of its application to air filters; finite filters; alternative definition of transmission ratio for finite filters; and finite filter with a finite termination. *Jour. Applied Physics*, October, 1938, pages 612–622, 17 illus., 35 equations.

An Objective Noise-Meter for the Measurement of Moderate and Loud, Steady and Impulsive Noises. A. H. Davis. Instrument of the microphone-amplifier-meter type has been adjusted for measuring equivalent loudness of noise. Instrument has been used for nearly two years for various noise measurements including those which the National Physical Laboratory has made on vehicle noise. Long description of instrument and results of tests.

Second article describes a circuit noise meter (psophometer) and its applications. *Instn. Electrical Engrs., Jour.*, August, 1938, pages 249–260, 261–274 and (disc.) 275–288, 29 illus., 11 tables.

Ice Elimination Equipment

More De-Icing Advice. The Royal Aircraft Establishment does not consider pastes in their present form a reliable safeguard. Correctly installed Goodrich equipment was found to be 90 percent effective in protecting leading edges and the Dunlop system satisfactory in principle, though certain operational difficulties have yet to be overcome. Imperial Airways believe the Dunlop system will be satisfactory though the necessary weight of this equipment will make serious inroads on payload. British Airways in experience with the Goodrich system found certain difficulties—notably a case when a ridge of ice collected on the wing upper surface just aft of the shoe. Successful results have been obtained by D.L.H. with the exhaust-heating methods of ice protection and development work on this method is recommended. Review of pamphlet giving findings of the Civil Airworthiness Committee on de-icing of wings, tail and control surfaces. *Flight*, December 22, 1938, page 578. *Aeroplane*, December 28, 1938, page 857.

Aircraft Instruments and Navigation

Junior Xacto Meter. Bowser meter for measuring fuel flow weighs only $12^1/_2$ lb. Few details. *Aviation*, November, 1938, page 50.

Kollsman Develops New Accelerometer. Kollsman accelerometer Type 312 has been developed as an aid both to maintenance men concerned with flight conditions encountered by the airplane, and to pilots. Instrument will indicate stress to which plane was subjected, or maximum flight stress may be noted by the pilot during flight, and pointer reset to zero to obtain maximum stress in landing. Few details. *Aero Digest*, December, 1938, page 74, 1 illus.

Labs Lick Five Tough Problems. New automatons to measure propeller vibration and ground-height, to give position bearing, to eliminate static, and to warn of stall. Demonstrations of the terrain-clearance indicator developed by United Air Lines, Bell Telephone Laboratories and Western Electric, Sperry-RCA automatic direction finder, United Air Lines radio static eliminator, and propeller vibration tester demonstrated by the Hamilton Standard Division of United Aircraft are discussed. Reference is made to the N.A.C.A.'s antistall warning hook-up. *Aviation*, November, 1938, pages 55, 56, 3 illus.

Simplified Layout Method for the Great Circle Track. T. P. Conlon. Method described will not only supply requirements of the pilot who cannot obtain a Gnomonic chart when he needs it, but also will be useful to the navigator who is limited as to room. Method is a true mechanical projection as used in mechanical drawing. Use of a compass with a radius approximating 20 in., a protractor which can take advantage of such a radius, and a straight edge, a fairly close approximation (depending upon scale) of the great circle track between two places, can be made without use of tables or prepared data. *Aero Digest*, December, 1938, pages 65, 66, 7 illus.

Miscellaneous Equipment

Back to the Catapult. Capt. H. C. Richardson. Historical background of catapulting, and analysis of the forces acting on the aircraft in assisted take-off. Types of catapult engines and launching cars for seaplanes, warming up, starting and condition from instant the car moves forward until end of impulse run are also discussed. To be concluded. *Aviation*, December, 1938, pages 26, 27, 76, 78, 80, 2 illus., 14 equations.

Cinema Aviation Relay. Cinema electrical relay by which operation of various aircraft units is effected. Coil operates on 400 cycles a.c. 1 amp. at 8 volts, 6-pole single-throw 5-amp. contacts, and relay operates in less than four cycles, or one-hundredth second. Few details. *Aviation*, December, 1938, page 49, 1 illus.

Fabric Fuel Tank Is Announced by Glenn Martin. Mareng fuel cell is made of fabric impregnated with synthetic rubber and successfully withstood 700 hours of violent vibration, still being gas tight. An example of its ability to slow up the leakage of gasoline when punctured by a machine gun bullet when attacked in an unnamed war is referred to. Short note. *Science News Letter*, January 7, 1939, page 9.

Testing Apparatus

Measurement of the Thickness of Metal Walls from One Surface Only. B. M. Thornton and W. M. Thornton. "Thickometer" for measuring the thickness of plates or tubes where access can only be had to one surface of the metal. By use of the Cambridge spot-light galvanometer, it is possible to measure with great accuracy potentials of the order of 50 microvolts. A current was found which would give this voltage drop across points so closely spaced that they would indicate the presence of local thinning in plates and tubes. Circuit common to all four-point methods of measuring resistance is described. Application of the method for measurement of plates, results of tests on corroded mild-steel plate, calibration of the instrument, and application of the electrical method to tubes of eccentric section are discussed. Institution of Mechanical Engineers paper. *Engineering*, December 16, 1938, pages 715–717, 9 illus., 2 tables.

The Time Lag in Gas-Filled Photoelectric Cells. A. M. Skellett. Time-Lag measurements described were made with a light chopper on a gas-filled cell of special design. Resulting response versus frequency characteristic exhibits the resonance oscillations predicted from theory, and calculation of the lag from the positive ion mobility agrees with that determined from this curve. Cell construction is such that secondary emission and disintegration of cathode by ion bombardment are eliminated even at high values of gas amplification. *Jour. Applied Physics*, October, 1938, pages 631–635, 3 illus., 1 table, 5 equations.

An Arrangement for Rapid Microphotometry. G. O. Langstroth and D. R. McRae. Modification of the usual "direct-reading" microphotometric procedure permits saving of time and labor in the photographic measurement of relative intensities of spectral lines, and hence is especially useful in spectroscopic methods of analysis. Description. *Optical Soc. Am., Jour.*, November, 1938, page 440.

Electron Microscopes. General principles of high-magnification electron microscopes with reference to that produced by Siemens and Halske in Germany. *Electronics*, November, 1938, pages 30–33, 9 illus.

Methods and Means for Determining the Natural Modes of Vibration of Mechanical Structures. H. C. Hayes and E. Klein. Simple method and means for determining experimentally the several natural resonant frequencies of any mechanical system and the location of the nodes of their respective standing wave systems. Its effectiveness is demonstrated by analyzing three modes of vibration of a ship's propeller. *Am. Soc. Naval Engrs., Jour.*, November, 1938, pages 519–526, 7 illus., 1 table, 4 equations.

The National Physical Laboratory—Physics Department. Research in radiology on the neon-tube radium detector and in applied radiology in the examination of metals, synthetic resins and mica. Continued. *Engineering*, November 25, 1938, pages 623–624.

Non-Destructive Testing. Magnetic and electrical, X-ray and gamma-ray, acoustical and general methods of testing are discussed. Review of discussion on non-destructive methods of testing organized by the Joint Committee on Materials and Their Testing, under the auspices of the Institution of Electrical Engineers. *Engineering*, December 2, 1938, pages 651–652.

The Month's New Instruments. New devices for measurement, inspection, testing, metering and automatic control. Few details. *Instruments*, November, 1938, pages 270–279, 35 illus.

Metals

Diffuse Electron Diffraction Patterns. J. T. Burwell. Diffuse electron diffraction patterns taken by reflection have been in the past, cited as proof that polished surfaces of metals are amorphous or very finely crystalline. In the present article it is shown that such patterns can be obtained from a large-grained crystalline surface and hence cannot be due to an amorphous phase but rather to the physical contour of the surface. *Jour. Chemical Physics*, December, 1938, pages 749–751, 4 illus.

High Strength of Furnace-Brazed Joints Explained. H. M. Webber. Properly made furnace-brazed joints have been shown to have great strength which, in the case of copper assemblies, is attributed to the alloying effect between copper and iron, and a knitting effect between the two iron surfaces. Effects of tightness of fit in joints; nothing gained by drive fits; effects of time in furnace; effects of heat treatment; grain refined by reheating; carburizing before or after brazing; why high strength is obtained; surfaces bound together; and higher alloy strength. To be continued. *Iron Age*, December 29, 1938, pages 30–34, 61, 10 illus.

New Applications for Press Work. J. D. Jevons. First issue—Drawing of thin-gauge alloy-steel sheet and strip for use in aircraft structures; possibility of producing deep drawn or pressed parts in free-machining varieties of metal such as brass and steel; and drawing of copper steels, stainless steels, Armstrong metal, copper, and special copper alloys.

Second issue—Deep drawing and pressing of new alloys are discussed including: cupro-nickel alloys; aluminum and aluminum alloys; aluminum utensils; crystal structure; magnesium alloys; zinc; precipitation-hardening alloys; plated, coated and clad sheet; lubricational coatings; protective and decorative coatings; chromium-plated sheet; and clad sheet.

Third issue—New processes for shaping sheet metal including: warm pressing and drawing; stretching; combined pressing and stamping; principle of impact extrusion process; field of application of these products and use of metals other than the apparently ductile ones; impact extrusion of brasses; theoretical considerations of this process; requirements for presses; selection of lubricants; and reasons for use of this process to an increasing extent. *Metal Industry*, December 23, 1938, pages 615–619, 5 illus.

Abstracts and Summaries—Symposium on Hardenability. Physics of hardenability; its relation to quenching; effect of silicon and aluminum additions; hardenability tests; hardenability of low-chromium steels; transverse hardness tests of heat-treated steels; designation of hardenability; hardenability of plain carbon steels; hardenability in light sections; and surface conditions. Review of American Society for Metals symposium. *Heat Treating and Forging*, November, 1938, pages 554–560, 3 illus.

The Automobile Research Committee. Behavior of bearing metals and crankshaft materials. Recent experimental work at the Institution of Automobile Engineers laboratory. Cast alloy and nitrided crank shafts gave favorable results both as regards crankpin and bearing wear. Chromium plated crankpins showed disappointing results, and of two crankpins tested the one showing least wear was the one with the thin deposit. Cast alloy with sorbitic structure and Vickers hardness test of 330 gave lower rates of wear. Failure of white metal bearings commences as a form of fatigue or cracking of the metal. Description of apparatus and procedure, and discussion of results. *Automobile Engineer*, November, 1938, pages, 441–444, 9 illus.

Effect of Casting Defects on Strength of Light Metal Castings F. Bollenrath & E. Schiedt. Several defective aluminum- and magnesium-alloy castings were loaded statically and dynamically up to fracture with regard to service stress. Opinions based on test results are presented for judging casting defects. *Luftfahrtforschung*, October 10, 1938, pages 511–516, 14 illus.

Corrosion-Resisting Process is Discovered. Process invented by M. Tagaya of Osaka Imperial University for corrosion-resisting alloy steel without nickel. By use of high frequency a powder containing 15 to 20 percent chromium and 10 to 15 percent copper is diffused into steel through a special melting process and product rolled into sheets less than 0.04 in. thick. Another corrosion-resistant product is reported to have been made with powder containing 8–18 percent chromium and 10–20 percent manganese. Brief reference. *Industrial and Engineering Chemistry, News Ed.*, December 20, 1938, page 670.

Iron and Steel

Gear Steels. P. M. Heldt. Reasons for the failure of automotive gears; effect of nickel in case-hardening steels; heat treatment and core properties of 2315, 2512, 3115, 4615, 4815, and Krupp alloy steels; direct-hardening gear steels used in the automotive industry; chief advantages of direct over case hardening; and properties of a slight modification of the 4640 specification used by the Warner Gear Company and of direct hardening chrome-vanadium steel 6145 used for transmission gears; and carbon-vanadium steel used for gears that are surface hardened by heating the surface progressively by acetylene torch and quenching immediately by a jet of quenching liquid. *Automotive Industries*, December 17, 1938, pages 788–793, 800, 3 illus., 2 tables.

Quality Control of Steel. R. F. Bisbee. Westinghouse tests for controlling the quality of steel for its products are described, especially the bond, sag, and enamel performance tests for steels to be vitreous enameled. *Iron Age*, December 29, 1938, pages 20–22, 4 illus.

Heat Characteristics of 5 Silicon-Chromium-Molybdenum Steels. A. E. White, C. L. Clark, and W. G. Hildorf. Through proper combination of silicon and chromium, five steels were developed which would possess a greater resistance to oxidation and sulfide corrosion at high temperatures. Usual creep tests gave little information on influence of lack of surface or structural stability on load-carrying ability or on ductility characteristics but it is believed that this information can be obtained from the stress-rupture results.

First issue—Chemical composition and tensile properties; impact resistance; creep resistance; rupture strength; and creep versus rupture strength.

Second issue—High-temperature stability; heat embrittlement tests; tensile properties of completed creep specimens; impact resistance of completed creep specimens; and metallographic structures of completed creep specimens and of stress ruptured specimens. Increased silicon content increases actual service life even though it decreases creep strength. *Oil & Gas Jour.*, December 8, 1938, pages 43, 45, 46, 48, 7 illus., 9 tables.

Inclusions and Gases in Steel. F. F. Franklin. Review of literature on these defects covers effects of gases and inclusions in steel, determinations and examinations, types and occurrences, and control. *Heat Treating and Forging*, November, 1938, pages 543–546, 4 illus.

Non-Ferrous Alloys

Ageing. Marie L. V. Gayler. Equilibrium diagrams of alloys which possess the property of age hardening, and characteristics of alloys which age harden. Mechanical properties, composition of alloy and temperature of ageing are discussed, including thermal changes, changes in density, dilatometric changes, changes in electrical resistivity, X-ray spectra, and in microstructure, corrosion, magnetic susceptibility, and incubation period. *Metallurgist Sup., Engineer*, October 28, 1938, pages 166–169.

Copper Alloys in Engineering. H. J. Miller. General copper alloys, turbine blading, creep properties, high-strength constructional materials, electrical applications, recently developed conductivity materials, materials for electrical applications, high-tensile-strength casting alloys, nickel bronze and wrought alloys. To be concluded. *Metal Industry*, November 18, 1938, pages 493–497, 4 tables.

Light Alloys for Aircraft—Problems of Their Fabrication and Application. H. Sutton. First issue deals with aluminum alloys, covering: Castings; heat-treatable casting alloys; pressure tightness; wrought aluminum alloys; double-heat-treatment type of improved duralumin alloy used in aircraft; Hiduminium; alloys for pistons and cylinder heads; light-alloy chains; and all-metal joints for pipe lines. Tables give test results on duralumin propeller forgings, comparative properties of light-alloy and steel mooring chains; and properties of sheets in soft and medium-strength British aluminum alloys.

Second issue is devoted to magnesium alloys, covering: Cast alloys; improvements in quality and a few facts about a new alloy developed especially for castings required to be pressure-tight (Magnesium 299, D.T.D. 350); wrought magnesium alloys; results of tests on magnesium-alloy propeller blades; properties of material in relation to design of aircraft structures; protection of aluminum alloys against corrosion; anodic treatment; organic protectives; protection of magnesium-rich alloys against corrosion; chromate treatments; fatigue and corrosion-fatigue properties; and effect of etching treatments. Continued. Midlands Metallurgical Societies paper. *Metal Industry*, December 16 and 23, 1938, pages 581–584 and 609–612, 8 illus., 3 tables.

Plastic Deformation of Lead, Copper, and Aluminum under Static Compression. W. J. Lyons. Investigation undertaken to obtain accurate numerical data on the rate of deformation of lead cylinders under various static loads. In comparison, tests have been made on copper and aluminum cylinders also. Dependence of deformation of lead on duration is found to be great under the higher loads, and much greater than the dependence in the case of copper and aluminum. *Jour. Applied Physics*, October, 1938, pages 641–646, 5 illus.

Welding

Durability and Fatigue Strength of Unwelded and Butt-Welded Chrome-Molybdenum-Steel Tubes at Various Mean Tensile Stresses. F. Bollenrath. Results of further tests undertaken by the D.V.L. on the durability and fatigue strength of chrome-molybdenum-steel tubes of 28-mm. external diameter and 1-mm. wall thickness under vibration stress at various mean tensile stresses. Deviations were made from the irregular sequence of stress reversals, actually existing in operation, with the most varied mean stresses at high fluctuating amounts for the upper and lower limiting stresses in order that durability and fatigue strength at constant stress deflections and various mean stresses could be determined in finite time. *V.D.I.*, December 3, 1938, pages 1412–1413, 7 illus., 2 tables.

Spot and Projection Welding. J. L. Miller. Advantages and disadvantages of projection welding which is said to have given remarkably consistent results on tensile tests, and with which several welds may be made at one stroke. Projection welding is compared with spot welding, and fundamental requirements of projection welding machines are listed. *Engineer*, December 23, 1938, pages 693–695, 13 illus.

Welding of Thin Light Metal Sheets by Means of Resistance-Fusion Welding. K. G. Gabler. In the method of electrical resistance-fusion welding, developed by Weibel, the abutting ends of two sheets, heated beyond a plastic condition are brought to a fusion temperature and welded without pressure. It is characteristic that the fused material, as in the case of gas fusion welding, runs into the open seam. Required heat is produced by alternating current of 200 to 500 amp. and 4 to 9 volts. Method requires special preparation of thin sheets either by flanging of the edges or by placing into the welding seam a piece of the same material corresponding to the seam form. Fine uniform structure is obtained and, since the range of the heating effect is not so great, there are only minor defects. Strength of the connection corresponds on the average to that of soft-annealed material. Corrosion tests in salt spray after 8 months showed no visible corrosion deposits. *V.D.I.*, December 3, 1938, pages 1399–1400, 8 illus.

Testing of Metals

Apparatus for High-Speed Repeated-Impact Testing of Metals under Separately-Applied Stress. G. C. Seager and W. H. Tait. Apparatus simulates conditions to which engine bearings are subjected and was designed for administering rapidly-repeated blows to a test piece which could simultaneously and independently be subjected to tensile or other stresses. Cracking of bearing metals in internal-combustion engines appears due to the simultaneous effect of a tensile stress on which is superimposed a rapidly-pulsating compression. Although the specimen elongates under test, blows continue to fall on the original point of contact. Instrument records automatically the number of blows before failure. *Engineering*, November 25, 1938, page 611, 3 illus.

Hairline Imperfections—The Nature of Hairlines and Methods for Their Detection in Semi-Finished and Finished Steel Products. C. L. Shapiro. First issue—Methods for detection and rating are described and various control techniques discussed. Second issue—Non-destructive testing for hairlines. Visual examination with the aid of surface coatings; magnetic test methods including Magnaflux test (described in great detail), flash magnetization method developed by Woolwich Arsenal, Fermango test, radiography; radioactive methods of examination; micro-chemical examination; and results of tests. *Iron Age*, December 8, 1938, pages 30–35, 5 illus.

Metallurgical Applications of Electron Diffraction. H. R. Nelson. Experimental method; applications to surface chemistry and to the study of thin metallic films, mechanically worked surfaces, and bearing surfaces and lubrication; and limitations of the method. *Jour. Applied Physics*, October, 1938, pages 623–627, 5 illus.

Non-Destructive Thickness Measurements. Method developed by A. Trost for detecting variations of thickness of walls of pressure tubes and gas bottles, thickness of the metal being determined by absorption of a beam of X-rays. Abstract from Stahl und Eisen, June 23, 1938. *Metallurgist Sup., Engineer*, October 28, 1938, page 165.

Quantitative Spectrographic Analysis—Standardisation of Technique. D. M. Smith. Excitation of spectra; solution methods; qualitative analysis and detection of impurities; quantitative analysis, including comparison sample method, internal standard method, auxiliary spectra, auxiliary alloys,

synthetic spectrum method, logarithmic sector, stepped sector, and non-recording microphotometer; and spectra of alloys. Author is an investigator at the British Non-Ferrous Metals Research Association. *Metal Industry*, November 18, 1938, pages 485–488, 1 table.

Radiomicrography. Technique and possibilities of the radiomicrography of metals have been investigated by M. F. Fournier of the French Air Ministry. Method serves to supplement ordinary microscopical examination when two or more metals of very different atomic number are concerned, and gives indication of the distribution of crystals, their geometric form and degree of homogeneity of solid solutions. Abstract from Revue de Metallurgie, August, 1938. *Metallurgist Sup., Engineer*, October 28, 1938, page 161.

Admiralty Laboratory at Sheffield. New metallographic and spectrographic and chemical analysis laboratories for the inspection of materials used in naval armament work. Building and laboratory equipment described. *Engineer*, December 23, 1938, pages 706–707, 6 illus.

Elasticity and Damping in Relation to the State of the Material. F. Forster and W. Koster. New apparatus for determining the modulus of elasticity and the damping capacity can be applied in two ways for investigation of materials and not only serves as a means of metallurgical research, but can also be used in various ways for non-destructive testing. Method completely precludes any mechanical stressing of the test piece during measurement. Method of measurement and results obtained are described including: moduli of elasticity and damping of pure metals; dependence of modulus and damping on temperature of metals and alloys; polymorphous transformation of alloys in the solid state; transition of alloys from ordered to disordered condition; characteristic influence of ferro-magnetic transformation on modulus and damping; investigations on modulus and damping of various homogeneous and heterogeneous alloy systems and influence of alloy additions; influence of grain size; precipitation hardening; internal stresses; detection of local defects study of intercrystalline corrosion; and use in technical investigations. Paper presented at the symposium on non-destructive testing. *Engineer*, December 2, 1938, pages 626–628, 18 illus., 2 tables, 3 equations.

Testing of Materials

Elastic Properties as a Measure of Hardness. S. R. Williams. Young's modulus of elasticity, or the modulus of stretch, and rebound methods which rest upon the elastic forces of restitution called into existence when an external force is applied to a body to change the distances between the constituent particles composing the body. Various devices are illustrated. Continued. *Instruments*, November, 1938, pages 283–287, 8 illus., many equations.

Evaluation of Stiffness. Saxl stiffness tester described is an instrument in which the test piece is clamped horizontally between a rotatable grip and the short end of a weighted balance arm so that the stiffness of the specimen is measured by the degrees of rotation necessary to bring the system into equilibrium. *India Rubber World*, December 1, 1938, page 47, 1 illus.

The Evaluation of Yield Value with the Sphere Viscometer. J. C. Williams and E. I. Fulmer. Various methods and formulas for determining yield value are critically reviewed and a method is proposed for determining this value by means of the sphere viscometer. *Jour. Applied Physics*, December, 1938, pages 760–764, 5 illus., 2 tables, 16 equations.

Non-Destructive Testing. Magnetic and electrical methods, X-rays and Gamma-rays, and acoustic and general methods. General discussion on non-destructive testing which was arranged by the Joint Committee on Materials and Their Testing, and which took place at the Institution of Electrical Engineers. *Engineer*, December 2, 1938, page 620.

Rubber

The Mechanical Characteristics of Rubber. F. L. Haushalter. Behavior of rubber as an engineering material in tension, compression, shear, and torsion. General effect of stresses; theoretical and calculated modulus of elasticity; rubber in compression with and without lubrication; load-deflection characteristics of rubber cylinders loaded as columns; effect of thickness on the compression curves of airplane shock-absorber disks; loading curve for a neoprene cylinder and a rubber slab; and high compression loading on 1-in. rubber cubes. To be continued. American Society of Mechanical Engineers paper. *India Rubber World*, December 1, 1938, pages 36–40, 15 illus., 4 tables.

Textiles

More Information Is Available on New Synthetic Textile Fiber. German textile fiber is based on acetylene without aid of any plant or animal raw materials. It has complete resistance to water, tensile strength the same, whether wet or dry, incombustibility, stability against almost all acids and alkalies, complete resistance to attack by putrefactive bacteria, and elasticity and electrical and thermal insulating capacities greater than natural silk. Acetylene is converted into vinyl chloride, and the latter into polyvinyl chloride, which can be worked into fiber and thread. Brief note. Wool made from casein in Germany is discussed in another note. *Industrial and Engineering Chemistry, News Ed.*, December 20, 1938, pages 669–670.

Meteorology

Farewell to Airplane Weather Soundings. J. A. Riley. System using radiometerographs in making weather forecasts, network of stations, equipment used, and advantages. *U.S. Air Services*, December, 1938, pages 19–20, 34.

More Atlantic Meteorology. Capt. F. Entwistle. Special problems in transatlantic services; wind effects; the ice problem; forecast problems; three routes used; and courses followed by the Hindenburg airship during 1936 to take advantage of meteorological conditions. Royal Aeronautical Society paper and discussion. Summary of times of passage and ground speeds over the three Atlantic routes at air speeds of 150 m.p.h. *Flight*, November 17, 1938, pages 459–462, 3 illus., 1 table.

Some Meteorological Aspects of Nebraska Tornadoes. H. Lemons. Nebraska experienced 121 tornadoes during the 22-year period 1916–37. Less than 20 entered from adjoining states, most of them coming from Kansas. Daily weather maps for all days on which tornadoes occurred in this period were examined to determine number of storms which originated at or near surface fronts. Time-areal distribution; tornado inception and paths; relationships between certain characteristics of tornadic origin and travels to certain features of their parent lows; and chance of encountering a tornado in Nebraska. *Monthly Weather Rev.*, July, 1938, pages 204–208, 8 illus.

Fuels and Lubricants

Resin Plasticizer in Lubricants. Lubricants can be improved and made resistant to high temperatures by addition of dibutyl phthalate (a material used to soften resins) and a resin as a thickener. Resistance to carbonization at high temperatures and good lubricating and viscosity characteristics claimed. Typical blend consists of mineral oil 16 parts; dibutyl phthalate, 3 parts; and polyvinyl acetate, 1 part. Brief reference. *Scientific Am.*, December, 1938, page 312.

Studies in Lubrication. F. Morgan and M. Muskat. Experimental friction coefficients for thick film lubrication of complete journal bearings. Description of apparatus and experiments, and discussion of results. *Jour. Applied Physics*, August, 1938, pages 539–546, 6 illus.

Ammonia as Motor Fuel in France. Recently developed process permits of using an antidetonating mixture of ammonia and hydrogen as fuel in ordinary combustion engines, the mixture being obtained by starting with liquefied ammonia of which 1.2 lb. is equivalent to 1 lb. of gasoline. Use of ammonia necessitates an installation a little more specialized than that called for by coal gas but storage tank is not as heavy. Tanks are less vulnerable to attacks than stocks of gasoline and cost of production is less than that of synthetic gasoline. Few details. *Automotive Industries*, January 7, 1939, pages 6–7.

Castor Oil as an Engine Lubricant. J. Dinitilhac. Experiment at the French Air Ministry showed that at about 285°F. castor oil is rapidly transformed into a rubber-like substance, and whole of the products formed by castor oil at this temperature is "cooked" at the temperature of the piston crown. While it would be possible to continue to build aircraft engines designed to be lubricated by castor oil it would mean a sacrifice of high acceleration, close fits, safeguards of tin-base bearing alloys, high take-off power and long engine overhaul periods. From Plein Ciel. *Automotive Industries*, January 7, 1939, pages 23–24, 2 illus.

Modern Petroleum Research. E. C. Williams. Fundamental aspects of modern research in oil are discussed covering: catalytic activities of certain metals toward hydrogenation; commercial development of truly synthetic gasoline for use in the highest octane motor fuels; possibilities of oil as a basic chemical material, as shown by the synthesis of glycerol from petroleum, and means available for accelerating or modifying the course of chlorination reaction. *Industrial and Engineering Chemistry, News Ed.*, December 10, 1938, pages 630–632, 4 illus.

Contribution to the Theory of the Heated Ducted Radiator. H. Winter. Method is developed by which reduction of flow quantity and resistance of a heated radiator (radiator under service conditions as compared with that in the cold condition) can easily be computed. For presentation of flow conditions, a symmetrically developed ducted radiator is used. Results are directly applicable to conventional unsymmetrical radiator designs in aircraft construction. Report of Goettingen Aerodynamic Research Institute. *Luftfahrtforschung*, October 10, 1938, pages 500–504, 5 illus., 17 equations.

Investigation of the Adaptability of Heat-Resistant Materials for Combustion Engine. F. Bollenrath, H. Cornelius, and W. Bungardt. Effects of temperature, exhaust-gas composition, and addition of ethyl fluid to fuel on nine heat-resisting materials for combustion parts were investigated to determine their resistance to scaling. Results of tests showed that the scaling resistance of all commercial alloys with Cr-Ni-Fe basis suffices for temperatures of 800° for exhaust-gas turbine blades. D. V. L. report. *Luftfahrtforschung*, October 10, 1938, pages 505–510, 13 illus., 3 tables.

Investigations on Control of High Exhaust-Gas Temperatures in Exhaust-Gas-Turbine Supercharging by Means of Internal Cooling. C. Schoerner. Methods of internal cooling of blades for the control of high exhaust-gas temperatures in exhaust-gas turbines for supercharging Otto-cycle engines were investigated at the D.V.L. on fixed blades with variously designed cooling air channels. Results obtained were transmitted mathematically to actual conditions of the rotating turbine wheel.

Temperature drops at the entrance edge up to approximately 25 percent and at the back of the blades up to approximately 50 percent of the temperature difference between cooling-air temperature and pressure temperature were obtained. Mathematical conversion of test results to conditions of the exhaust-gas turbine at altitude lead to the conclusion that gas temperatures of about 850°C. are admissible for a turbine of large absorption power with such blades. By supplying compressed air further increase to 900–950° is possible. D.V.L. report. *Luftfahrtforschung*, October 10, 1938, pages 495–499, 5 illus., equations.

Problems of Exhaust-Gas Turbine Design. K. Leist. Characteristic differences in the requirements for construction of exhaust-gas turbines and steam turbines are demonstrated and effect of lightweight construction on performance range, specific weight, and stress conditions are discussed with approximate equations and consideration of similitude. A mathematical table for graphical determination of principal data for exhaust-gas turbines is described.

From stress measurements on materials and temperature measurements on turbine blades, conclusions are drawn as to admissible gas temperatures, which are compared with measured exhaust-gas temperatures. Means of temperature control are discussed.

Development points to use of uncooled gas and application of cooling methods to endangered turbine parts. Exposure of blades to outside air, as D.V.L. tests demonstrated, is a suitable means for keeping blades cool. Fundamentals of control of turbines are considered. D.V.L. report. *Luftfahrtforschung*, October 10, 1938, pages 481–494, 19 illus., 1 table, equations.

Resistance to Flow through Nests of Tubes. R. P. Wallis and C. M. White. Experiments undertaken in the King's College civil engineering laboratories to find the overall resistance of nests of tubes arranged both in parallel and staggered formation. Pressure distributions around individual tubes were measured and flow motions observed so that overall resistance could be separated into simpler parts. Variations of total resistance of nest with varying airspeed for both formations are given. Water was used for preliminary tests but main work was with air, a centrifugal fan drawing air through the nest. To be continued. *Engineering*, November 25, 1938, pages 605–607, 7 illus., 2 tables, many equations.

Stresses and Deformations in Pipe Flanges Subjected to Creep at High Temperatures. J. Marin. Analyses of stresses and deformations produced in a circular ring of rectangular cross section subjected to twisting couples uniformly distributed along its center line. Such a solution will also give an approximate analysis of the pipe flange. Deflection theory is also developed for straight beams subjected to bending accompanied by creep. *Journal Franklin Institute*, November, 1938, pages 645–657, 6 illus., 31 equations.

Cylinder Cooling and Drag of Radial Engine Installations. K. Campbell. Paper, and discussion by F. M. Owner (comparing British and American practice), W. Worth, and A. T. Gregory. *S. A. E. Jour. (Trans.)*, December, 1938, pages 515–520, 18 illus.

Engine and Fuel—Progress, Problems, and Experiences. G. Leunig. Hanomag feeding system for the use of pulverized coal in engines is illus-

trated in a cross-sectional drawing, and experiences with engines using pulverized fuel are described in a review of engine and fuel progress and problems.

Discussion covers: liquid, gaseous, and solid fuels used in engine operation (tests and evaluation of liquid fuels, Diesel-engine operation with heavy-boiling fuels, gas power plants, performance increase of gas-driven automotive engines, and pulverized-coal engines); method for increasing performance and economy (mixture formation in gasoline and Diesel engines, possibilities and limits of increases in r.p.m. effective pressure, ignition delay and detonation process, development problems of the two-cycle Diesel engine and drawing of an oil cooled piston of a double-piston two-cycle Diesel, and tests on gasoline engines with fuel injection); special problems in design and testing of engines (large engines of light construction, automotive engines, noise reduction of engine test stands); and the operation of engines for power plants, buildings, and farms. Review of V.D.I. papers presented at Augsburg, 1938. *V.D.I.*, December 3, 1938, pages 1401–1409, 12 illus.

Engine Design and Materials. D. R. Pobjoy. Trends in aircraft-engine design are traced, including: merits of the sleeve-valve engine; cylinder arrangements considered to avoid increasing piston diameters and consequently reducing rotational speeds for large powers; advantages of the H-type engine; turbo blowers; compression-ignition engines; materials; and trends in engine details such as crankcases, cylinders, pistons, piston rings, exhaust valves, spark plugs, magnetos, crankshafts, lubrication systems, and plain bearings. *Flight*, December 15, 1938, pages 550, 550a–550d, 10 illus.

Powdered Fuel Engines Tested. Experiments to determine whether high rates of wear encountered on coal dust Diesel engines can be reduced to practicable proportions by suitable choice of materials for liners, pistons, and rings were undertaken by the British Fuel Research Station. Coal ash was injected at a constant rate into the carburetor intake of a single-cylinder gasoline engine running on gasoline under controlled conditions of load and speed and liner, piston and ring wear were measured after suitable intervals.

Some 27 combinations of materials were tested, and influence of rate of ash feed and fineness, and type of ash were also investigated. Influence of liner hardness and fineness upon wear are shown. Certain types of chromium-plated liner in conjunction with ordinary cast-iron pistons and rings gave the best results. *Engineer*, December 23, 1938, page 700, 2 illus., 3 tables.

Penetration of Oil Sprays. P. H. Schweitzer. Sprays of short duration were investigated to determine the characteristics of such sprays and to get an insight into the building-up process. Penetration of the spray tip in consecutive small-time intervals was determined by a sensitive electric content upon which the spray impinged. Factors having a considerable effect upon spray tip penetration are: injection and chamber pressures, orifice size and shape, and oil viscosity. Dimensional analysis served to establish certain relations by which effect of most important variables on spray tip penetration can be calculated. The ballistic pendulum determined the mean velocity of the oil droplets by measuring the effect of their impact on a plate. Even the very short duration of the injection period of the high-speed Diesel is much longer than the aerodynamic building-up period. Therefore spray in ordinary Diesel engines is not influenced by injection duration. *Jour. Applied Physics*, December, 1938, pages 735–741, 14 illus., 1 table, 5 equations.

Tightness of Piston Rings for Internal Combustion Engines. C. Englisch. Insight is given as to the effectiveness of piston-ring packing determined in the medium r.p.m. range. The author points out the manner in which changes in one or the other of the important requirements for the condition of a piston-ring packing affects the pressure ratio on the packing and the extent of the gas losses. Test results are shown in graphs and are discussed in detail. *A.T.Z.*, November 25, 1938, pages 579–584, 16 illus., equations.

Engine Fuel and Lubricant Testing

Anti-Knock and Mixture Distribution Problem in Multi-Cylinder Engines. A. J. Blackwood, O. G. Lewis, and C. B. Kass. Tests made on an 8-cylinder inline overhead-valve engine to determine why automobile engines in apparently identical condition should differ so widely in their antiknock requirements.

Description covers: analysis of exhaust gas in this test; tests on a series of fuels of different volatility ranging from regular-grade gasoline up to butane to determine effects of volatility on distribution characteristics; tests to determine the effects of manifold design on mixture distribution as well as on maximum power and economy; check of the ignition timer; tests on knocking tendencies of individual cylinders and on octane-number requirement of each cylinder; estimation of maximum possible difference in octane-number requirements of individual cylinders when conditions are such that cylinder that receives the worst knocking mixture distribution simultaneously receives the greatest spark advance and minimum difference in requirements. A.P.I. paper. *Automotive Industries*, December 24, 1938, pages 821–822, 825, 1 illus., 3 tables.

Rating Aviation Fuels in Full-Scale Aircraft Engines. H. K. Cummings. Completion of first program and progress made on the second program. Report of Cooperative Fuel Research Committee. *S.A.E. Jour.* (*Trans.*), December, 1938, pages 497–503, 8 illus., 3 tables.

Engines

Aero-Motors at the Paris Aero-Show, 1938. Characteristics and output of 87 aircraft engines are given in a two-page table, covering 19 British, 13 Czechoslovakian, 41 French, 8 German, 2 Polish and 4 American engines, and including four compression-ignition, 37 radials, 25 inverted-inline of four or six cylinders, 9 inverted and 5 upright vees, 4 H-type, 2 rotaries, and 5 horizontally opposed.

Hispano-Suiza liquid-cooled H-type with 2400 hp. rating is the most powerful but has not yet been flown. Clerget-Diesel gives 2000 hp. normally and is fitted with the only examples of turbo-superchargers on view. Thirteen engines are normally rated at 1000 hp. and upward. Daimler-Benz D.B.602 airship Diesel has the lowest fuel consumption claimed (0.387 lb./hp.-hr.) while the Napier Dagger VIII shows up best of the gasoline engines (0.430 lb./hp.-hr.). Forty-eight engines are supercharged, 5 having two-speed. Bristol Pegasus XVII is rated at the greatest height (14,750 ft.), the Hispano H also having this rating but not yet flown. A Hispano-Suiza with an experimental three-speed blower was shown.

Nose of the 2400-hp. Hispano illustrated in two views is so long it can be buried in the wing. The Loraine Sterna 1250-hp. water-cooled vee with long shaft drive, reduction gear and oppositely-rotating propellers, which was developed for the Koolhoven FK-55 single-seater fighter, is illustrated as well as photographs of other engines. *Aeroplane*, December 7, 1938, pages 750–753, 10 illus., 1 table.

Interesting Characteristics of Two German Engines. Daimler-Benz D.B. 600 12-cylinder inverted liquid-cooled engine develops 1040 hp. at 3600 meters. According to M. Heinkel and confirmed by others, output of the engine has been pushed up to 1300 hp. and to 1800 hp. at 3500 r.p.m., giving an efficiency of 53 hp./liter. Centrifugal supercharger located on the side of the engine delivers into the carburetor having an automatic pressure limiter disposed between.

Junkers Jumo 211 12-cylinder inverted-vee engine with direct injection of gasoline develops 1200 hp. while consuming, full throttle, only 200 to 220 gr./hp.-hr. due to direct injection, independent and exact for each cylinder. Junkers has produced an exhaust nozzle which recovers a part of the kinetic energy of the gas producing a supplementary horizontal propulsion force of around 15 percent. Long descriptions of both engines. *Les Ailes*, November 24, 1938, page 7, 6 illus.

International Parade of Aero Engines. W. F. Bradley. Description of the Paris Aero Show giving details of the following engines and parts: 6 Renault aircooled engines; *Potez inverted-vee 8 and the 20-hp. inline with turbine at each end of the shaft; Hispano-Suiza H-type of same cylinder elements as the Y models, having provision for firing through the propeller shaft, and developing 2600 hp. at ground level; changes in liquid-cooled Hispano models; Napier Rapier and Dagger; *Mercedes-Benz D.B.600 inverted-vee 12-cylinder liquid-cooled engine developing 1050 hp. at 2400 r.p.m. for take-off; *Mercedes-Benz 1300-hp. 16-cylinder Diesel for Zeppelin service; Junkers Jumo 211 12-cylinder inverted-vee liquid-cooled 1200-hp. gasoline engine; B.M.W. 880-hp. 9-cylinder radial; Bramo-Fafnir 1000-hp. 9-cylinder radial; Argus and Hirth 12-cylinder inverted air-cooled engines; *Bristol Taurus sleeve-valve 14-cylinder said to develop over 1000-hp. at medium altitude; *Bristol Hercules sleeve-valve engine to be produced in France; DeHavilland Gipsy inverted aircooled 12-cylinder; *S.N.C.M. 9-cylinder radial with direct gasoline injection; *Sterna 12-cylinder vee liquid-cooled engine with outboard propeller shaft extending 60 in. from the engine nose; Coatalen 12-cylinder liquid-cooled vee Diesel; *Clerget 14-cylinder aircooled and 16-cylinder vee water-cooled (1500 to 2000 hp.) engines; Mawen radial models with revolving head performing valve operations; Rolls Royce Merlin 12-cylinder having reduction gear and a two-speed blower and producing 1000 hp. at 3000 r.p.m. at ground level and 1265 hp. at 10,000 ft.; Farman two-turbine blower; Redynam dynamic vibration damper; Sarazin dynamic torsional vibration damper; and *Renaux pneumatic engine mounting.

Short references to these engines except in cases indicated by an asterisk where more details are given. *Automotive Industries*, December 24, 1938, pages 814–817, 825, 8 illus.

Paris Aeronautical Show. Review of exhibits including: twelve Walter engines; Vion compass and instruments; Potez 12-D 12-cylinder horizontally-disposed engine developing 450 hp. at 2400 r.p.m. at 3000 meters, and 500 hp. for take-off (few details), and other Potez engines; "Aérazur" balloons and vehicles transformable to workshops or laboratories; Napier Rapier VI 370 to 400-hp. and Dagger VIII 970 to 1000-hp. engines; Corset electric remote indicating device weighing only 1700 gr. for gauging two different reservoirs; Wright Cyclone; *D.F.* remote controls; Bozec and Gautier "centralizer of controls"; Merwille light propellers; and Zodiac balloons. Brief mention in most cases. *Les Ailes*, December 15, 1938, pages 7–8, 2 illus.

Present Status of Aircraft Diesel Engines. A. E. Thiemann. Progress of aircraft Diesel engines since 1934 is reviewed. Characteristics of the Jumo 205 two-cycle Diesel are compared in a table with those of the Hispano-Suiza 12Y21 using 100-octane fuel and Coatalen four-cycle Diesel at take-off. Weight, horsepower at take-off, maximum speed, wing area, and weight per horsepower are given for the Sikorsky, Lioré et Olivier, Loiré 102, Blohm and Voss Diesel, Do-18 (Diesel engines) and Do-18 (Hispano-Suiza engines) flying boats. Influence of the type of take-off, take-off performance, and type of engine on the payload of the Do-18 for 4000 km. is shown. Table gives recent data on the Coatalen 600-hp., Mercedes-Benz OF-2 800-hp., N.A.C.A. 60-hp. single-cylinder, BMW, Bristol Phoenix 650-hp. (1935), Clerget double-row 500-hp. four-cycle Diesel engines, Botali 350-hp., Salmson 600-hp., ZOD-260 260-hp., Jumo 205 600-hp., Deschamps inverted-vee 1200-hp., Ricardo 66-hp. single-cylinder, and N.A.C.A. 76-hp. single-cylinder two-cycle engines. Photographs illustrate the time-expansion of the Clerget engine, and drawings show the piston of the Jumo, cylinder head of Mercedes-Benz airship and aircraft Diesel engine, and parts of the Botali, Salmson-Szydlowski U, and ZOD 260 two-cycle Diesels. *A.T.Z.*, November 10, 1938, pages 547–553, 13 illus., 5 tables.

Progress in Aircraft Engines. Progress in aircraft engines as indicated at the Paris Aero Show from the point of view of the mechanic, including cylinders, regulation, carburetors, ignition, and starting. *Les Ailes*, November 24, 1938, pages 18–19.

A Working Partnership. A new civil-rated aircraft engine, the 890-hp. Bristol Perseus XIVc has completed a very successful Air-Ministry approval test with a German V.D.M. electrically operated fully-controllable propeller. Cunliffe-Owen Flying Wing is equipped with two of these power plants. Short note referring to tests and giving a few figures on the Perseus XIVc.

A second note gives performance figures for the Bristol Aquila civil-rated 9-cylinder sleeve-valve radial having maximum take-off of 600 hp. at 3000 r.p.m. *Aeroplane*, December 7, 1938, page 759.

British Aero-Motors of 1938. Photographs of 25 British aircraft engines and table giving specifications and performances of 57 engines. *Aeroplane*, November 23, 1938, pages 655–659, 25 illus., 1 table.

Echoes of the Distance Record. Details of the carburetion systems used on the Bristol Pegasus XXII engines of the Wellesleys which made the record-breaking nonstop flight from Egypt to Australia. This was the first time a record had been made in which the whole of the Hobson Master Control scheme had been used. Leader's story included. *Flight*, November 17, 1938, page 458.

For Power and Fuel Economy. Why and wherefore of the two-speed supercharger are discussed and the Armstrong-Siddeley two-speed supercharger as used in the Tiger VIII (862 and 782 max. hp. developed at 6600 and 15,000 ft., respectively) is described. Operation is illustrated in drawings. *Flight*, November 17, 1938, pages 437–438, 2 illus.

Specifications of Engines. Specifications and performances of 53 American engines mentioned in the directory of military aircraft. *Aviation*, November, 1938, page 42.

Parts and Accessories

See How They Run. Spark-plug runner, electrically driven, within a predetermined torque limit has been developed at the British Air Ministry's request by Smali Electric Motors, Ltd. for removing and replacing aircraft-engine spark plugs. *Flight*, November 17, 1938, page 462, 1 illus.

An Elastic Connecting Rod. During the cycle of operations the distance between the two bearing centers of the Goinard connecting rod is said to vary considerably. At the termination of the suction stroke it is claimed that the inertia of the piston tends to compress the rod so that its travel is increased, thus drawing in from 3 to 8 percent more mixture into the combustion chamber. During the explosion stroke the rod at first shortens

slightly absorbing energy which is dispelled during the exhaust stroke when the rod lengthens, causing the piston to rise above its normal position, thus increasing scavenging efficiency. On single-cylinder tests b.hp. increased from 6.59 to 8.56 and fuel consumption fell from 10.384 to 8.33 oz./b.hp.-hr. Very brief note and illustration. *Automobile Engineer*, October, 1938, page 354, 1 illus.

Aircraft Radio

Aero Radio Digest. 1939 RCA radio designed specially for private fliers. Sperry Flightray for instrument flight and instrument landing. Nilvar alloy used in radio construction because of its relative immunity to size changes over a wide temperature range. Learadio direction finder loop mounted within a transparent streamlined housing. Dunmore patent covering a variety of means for actuating the control surfaces and the throttles of an airplane through electromagnetic couplings with the receiver circuits, and providing for utilizing the glide path, the localizer, and the two markers. Learadio U.H.F. aircraft receiver for C.A.A.'s development work on ultra-high frequencies, and the U.H.T. transmitter. Brief descriptions. *Aero Digest*, December, 1938, pages 77, 78, 5 illus.

Aviation Radio. D. Fink. First issue—Absolute altimeter developed jointly by United Air Lines and Western Electric. Sperry-RCA direction finder pointing automatically and continuously to tuned-in station. Long descriptions.

Second issue—Brief reference to the Lear Radio Compass, Model ARC-6, with an automatic motor-driven follow-up mechanism, which at all times keeps the loop pointed at the station received. Digests of two new reports from C.A.A. engineers are given which show what is ahead in the U.H.F. aircraft services, looking to the time when every ship is equipped for 75 mc. cone-of-silence, fan, and boundary-marker indications, and when, perhaps, traffic control is transferred to the ultrahighs as well. Fan marker at Bowie is described by McKeel, Lee, and Metz. Second report, by P. D. McKeel, describes a superheterodyne receiver suitable for use on any of the ultra-high frequencies assigned to aircraft use. *Aviation*, November and December, 1938, pages 48, 49 and 43, 44, 7 illus.

The Business of Getting Down. Systems used in Germany and at Le Bourget and Croyden airports for landing by radio in bad weather are discussed. A short note entitled "ZZ-ing into Heston," describes the ZZ system of blind approach. *Aeroplane*, November 16, 1938, pages 625–627.

C.A.A. Plans for 1939 Aircraft Radio Progress. H. W. Roberts. Set-up of the Civil Aeronautics Authority in regard to radio plans and coming radio aids. Abolition of the 278 kc. frequency for airport traffic control and its substitution by the 125 mc. frequency, order for Western Electric Adcock-type radio direction finders and development of an U.H.F. radio teletype circuit between ground stations and aircraft in flight are mentioned. *Aero Digest*, December, 1938, pages 57, 58.

Radio Communications Keep Up Good Air-Liners. British radio services are described in detail including: channels of communication; meteorological reports; stations; use of teleprinters; speed of operation and fatigue; staff at a radio station; messages in ciphers and private codes; and possible application of special channels such as the spectrum of frequencies between 1 and 10 meters. *Aeroplane*, December 21, 1938, pages 817–821, 3 illus.

Change of Front in America. Editorial comment criticizing the American radio-beacon system and pointing out that the Civil Aeronautics Authority has ordered three Adcock D/F stations for installation at Newark, Pittsburgh, and Washington. *Flight*, December 22, 1938, page 570.

Position Finders Developed to Tell Pilot Where He Is. Position finder developed by H. Stark consists of a translucent map below which are two translucent screens with spaced parallel lines, the three plates being turnable. One ruled plate is turned until its lines are pointed in the same direction as a bearing just taken on one station and the procedure is repeated with a bearing on another station and the other ruled screen. Intersection of two lines is the point where the pilot is located.

Automatic direction finder developed in England by O. G. E. Roberts and J. A. McGillivray, and the Sperry automatic direction finder are also described briefly. *Science News Letter*, December 10, 1938, pages 373–374, 1 illus.

Provision for Blind Landing. British Air Ministry has decided to equip 40 R.A.F. stations with apparatus for landing in conditions of bad visibility. The Lorenz system is said to have been chosen. Brief reference. *Flight*, November 24, 1938, page 480.

Photography

High-Speed Photography Demonstrated. Exposures of 1/100,000th second at a rate of 600 per second are made possible by the new process of high-speed photography developed by H. Edgerton of M.I.T. and Arthur D. Little, Inc. Electronic control device gives intense flashes of light from gas-filled tubes and individual flashes can be controlled so that the intervals of illumination and darkness are extremely accurate. Only one photographic plate is exposed for a cycle of motions. Brief note. *Industrial and Engineering Chemistry, News Ed.*, December 20, 1938, page 673, 2 illus.

A Physical Density Comparator. M. H. Sweet. Density comparator described was constructed using filtered tungsten radiation and Polaroid plates as a means for obtaining an accurate standard of comparison. In order to measure the densities of small areas of the negatives and print, high flux concentrations were used. Infrared was filtered from the total radiation by submerging the incandescent source in a tank of water. A water lens was used to condense the light. Instrument permitted the measurement of both transmission and reflection densities. *Optical Soc. Am., Jour.*, September, 1938, pages 348–353, 7 illus.

Aeronautical Industry and Production

Exports at $53,335,175. Total value of aeronautic exports during the first nine months of this year amounted to $53,335,175, representing an increase of 93 percent over the $27,426,352 for the same period last year. *Aero Digest*, December, 1938, page 37.

Production of Aircraft at the Beech Factory. Description of layout of buildings, duties of the Production Planning Department, and Production equipment. *Aero Digest*, December, 1938, pages 47–49, 66, 12 illus.

Production of Aircraft Shows Overall Increase. Production of aircraft in the U.S. for the first nine months of 1938 was 4 percent more than the total number of aircraft manufactured in the first nine months of last year, according to C.A.A. statistics. While there was a decrease of 28 percent in aircraft for domestic civil use, production of military aircraft jumped 95 percent, and 36 percent in planes built for export. Brief note. *Aero Digest*, December, 1938, page 15.

The Story of Hawker-Siddeley Aircraft, Ltd. History of each company of the Hawker-Siddeley group including Hawker Aircraft, Ltd., Gloster Aircraft Company, Sir W. G. Armstrong Whitworth Aircraft, Ltd., A. V. Roe and Company, Armstrong Siddeley Motors, Ltd., and Air Service Training, Ltd. Photographs of some of the early airplanes are given. "An Essay in Biography" by C. G. Grey gives the history of men due to whose ability this combine was built. *Aeroplane*, November 16, 1938, pages 601–616, 36 illus.

Pilots

The Field of Flight in Relation to Aeronautical Progress. Lt. Pilot P. Magini. After having distinguished a mechanical field and a physiological field of flight, and having considered the effects from the point of view of the machine and of the human being, the author examines summarily the elements constituted by the psychio-physiological aspects of flight demonstrating the influence which such elements can have on the ulterior development of aeronautical progress. *Rivista Aeronautica*, November, 1938, pages 297–312, 1 illus.

Japanese High-Altitude Aviation Station. Station on Mount Fuji, at 3700 meters altitude, is used as an aero-medical center for research on the conditions existing and general hygiene at high altitudes as well as on the physical examination of candidates for aviation. Brief reference. *Les Ailes*, December 15, 1938, page 5.

Aviation Medicine—Its Responsibilities and Problems. Lt. Comdr. E. Liljencrantz. The eye in aviation; the eye and blind flying; psychological examination; results of psychological tests as practiced at the Naval Air Station at Pensacola; maintenance of the flyer; effects of centrifugal force; altitude; provision for substratosphere flight; carbon monoxide poisoning; aeroneurosis; and pilot failure. *U.S. Naval Inst. Proc.* December, 1938, pages 1753–1760.